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SECTION 1

GEOLOGY AND TECTONIC EVOLUTION OF THE YARROL PROVINCE

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The purpose of this section is to provide a basis to assess the Yarrol Province in terms of permissibility for the occurrence of specific types of mineral deposits, considering the potential for the development of mineralising systems based on the rock units and their environment of formation — lithotectonics. The lithotectonic evolution of the province is relevant for the identification of deposits formed essentially contemporaneously with their host rocks. Epigenetic deposits, which involve two lithotectonic environments — one for the host and one for the mineralising system, are considered in terms of their mineralising system with intrusive bodies dealt with individually because of the variety of associated deposits.

The following description of the geology and evolution of the Yarrol Province refers to "resource evaluation units" (REUs). This term incorporates information on age and rock type and reflects a specific depositional environment. REUs have been defined to facilitate deposit model classification as well as the development of thematic maps used to identify tracts permissive for particular deposit types. In describing the distribution of REUs it needs to be recognised that delineation under cover is interpretative.

GEOLOGY

Comprehensive reports about geology in the Yarrol area have been written by Kirkegaard & others (1970), Dear & others (1971), Willmott & others (1986), Donchak & Holmes (1991), and most recently the entire area has been remapped resulting in revision of the stratigraphy and new interpretations of the tectonic history (Yarrol Project Team, 1997; refer Figure 2 and Yarrol GIS package). The following is a summary based on the most recent mapping and interpretations of the GSQ. Alternative models are noted in the text.

Late Silurian to Middle Devonian — Oceanic Island Arcs/Exotic Terranes

The Upper Silurian to Middle Devonian sequences consist of marine volcaniclastic sediments, fossiliferous limestones, and some primary volcanics. These rocks occur as several separate outcrops, which have been interpreted in two ways:

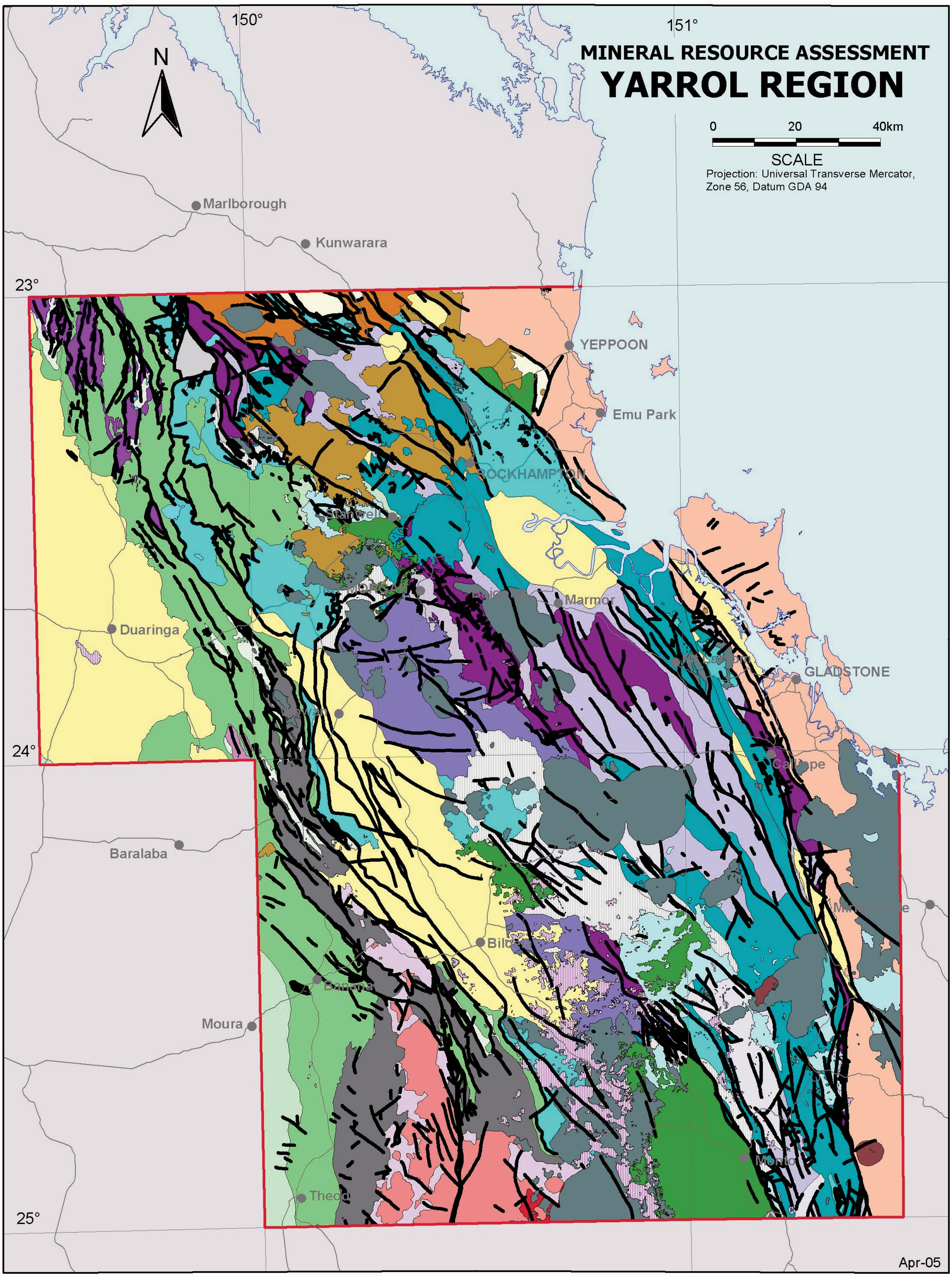
1. that they were formed by ocean island arcs which would have later accreted with the main continental margin, thought to occur around the Anakie Inlier area (Murray, 1986), and

2. that the Yarrol Province developed entirely in a continental arc setting (Henderson, 1980; Morand, 1993a,b).

The most recent work undertaken by the GSQ (Simpson & others, 1998; Murray & others, 2003; Murray & Blake, submitted) supports the interpretation that these rocks are exotic terranes and were formed as ocean island arcs and possibly microcontinents.

The Upper Silurian to Middle Devonian geological units are divided into four different REUs representing distinct exotic terranes. The four groups (Calliope, Erebus, Craigilee and Mount Morgan REUs) are not in stratigraphic contact with each other, but are bounded by faults, or occur as inliers surrounded, and

Figure 02 - Tectonic Map



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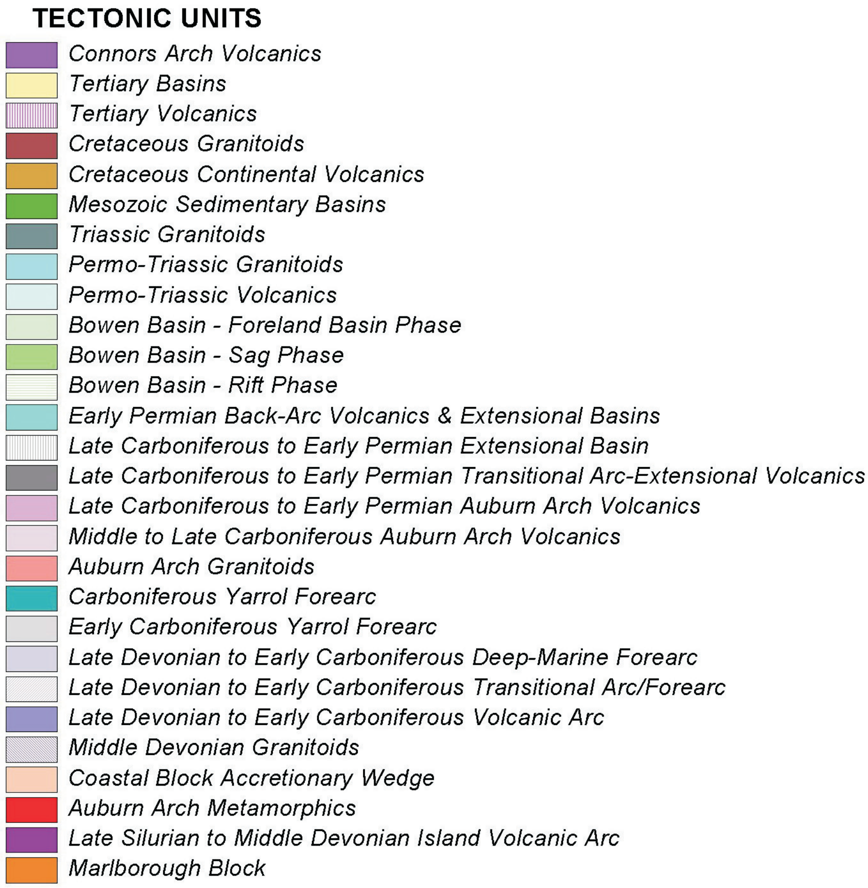


unconformably overlain, by the Upper Devonian to Lower Carboniferous rocks (REU Map — Figure 3). The Calliope REU comprises the Calliope beds, the Erebus REU comprises the Erebus beds, the Craigilee REU comprises the Craigilee beds, and the Mount Morgan REU contains the Capella Creek Group and Marble Waterhole beds. These units vary in stratigraphic succession and rock types, and despite the present proximity of these assemblages their coral faunas show significant differences. Although partly overlapping, these assemblages also represent different time ranges (Murray & Blake, submitted).

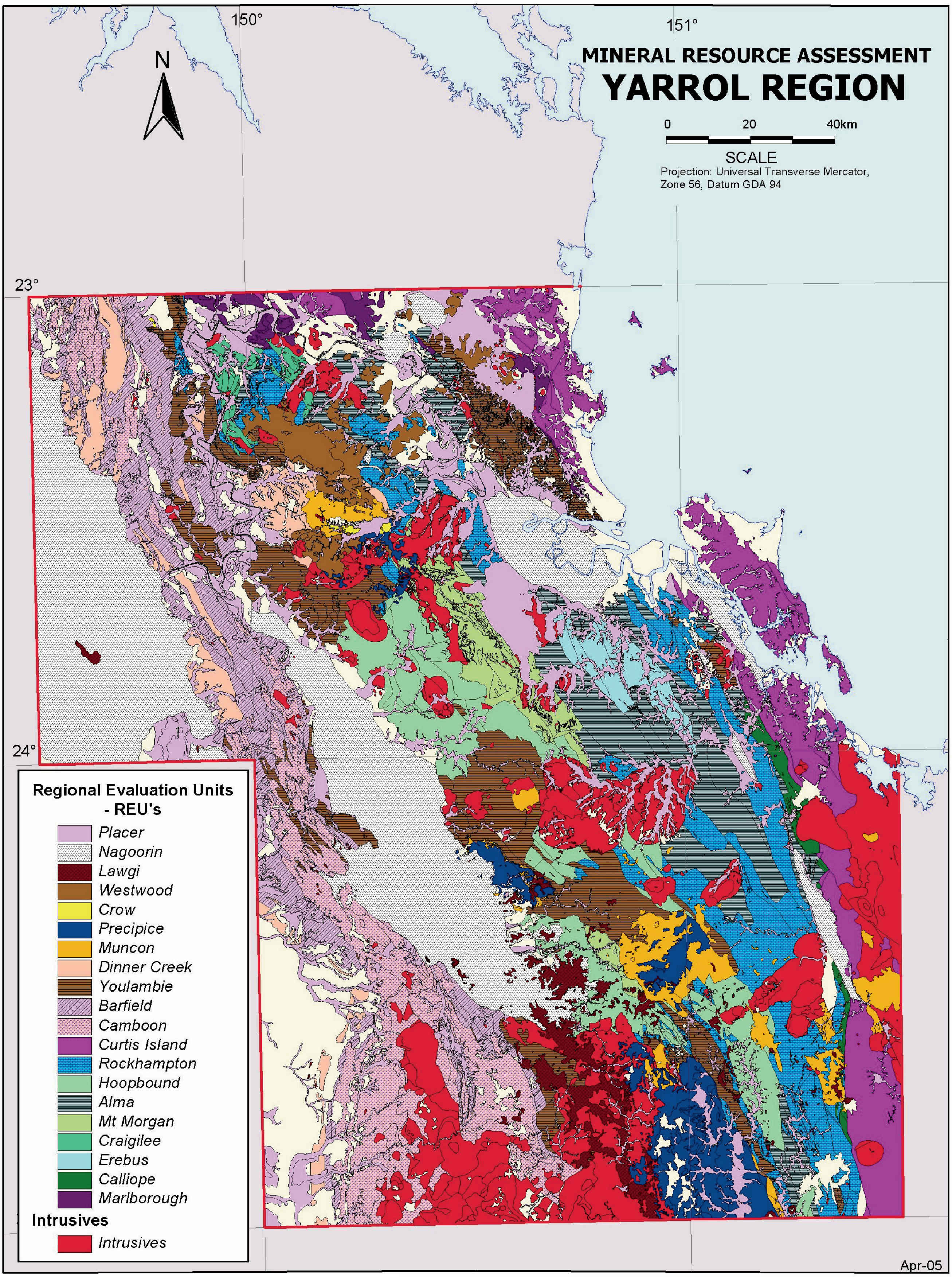
Calliope REU

The Calliope REU is a belt of rocks extending southward from the Yarwun area on the Gladstone sheet to Many Peaks on the Monto sheet. The REU, comprising the Calliope beds, is dominated by volcaniclastic sedimentary rocks with minor lava that are primarily basaltic and andesitic in composition with some dacite. Limestones are a minor part of the REU, but form large outcrops in places. Most of the sequence appears to be of Early to Middle Devonian age, but mid-Ordovician conodonts have been recovered from a limestone lens at one locality. The location of these rocks near the Yarrol Fault system is similar to that of Cambrian and Ordovician strata in the Tamworth area of the southern New England Orogen. The relationship to the surrounding Siluro-Devonian rocks is unclear.

The Calliope REU forms a geophysically distinctive belt with very low radiometric and strong magnetic responses. This magnetic belt, however, also includes part of a younger Upper Devonian unit, and appears to represent a zone of mafic intrusives. Some of the finer grained units within the Calliope beds display a cleavage, which dips steeply to subvertically towards the east-north-east, sub-parallel to the cleavage in the Erebus beds and the Mount Alma Formation. Although they have been considered younger than the Erebus beds (Morand, 1993a) most dates are, as yet, confined to the Early Devonian. An exception is a conglomerate within the Devonian sequence that contains limestone clasts of both Late Ordovician and Devonian age.

Given the presence of proximal volcanics, marine fossils, and based on geochemistry the Calliope REU is considered to have been deposited in an ocean island arc setting.

Figure 03 - Regional Evaluation Units



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Erebus REU

The Erebus REU is a belt of rocks extending south-east from Raglan on the Bajool sheet to Catfish Creek on the Calliope sheet. This REU, comprising the Early to Middle Devonian **Erebus beds**, is dominated by sandstone and conglomerate sourced from rhyolitic volcanics, with minor limestone and rare primary felsic volcanics. In the field many outcrops have a tuffaceous appearance, suggesting that there may have been some pyroclastic eruptions. Regional metamorphism has destroyed any microscopic textures that may have confirmed a pyroclastic origin. Basaltic and andesitic volcanics or volcaniclastics are rare and limestone is a minor component, although large outcrops occur in places. Most of the limestones display some recrystallisation, with the better-preserved outcrops containing common crinoids, corals, stromatoporoids, and lesser brachiopods, that indicate a shallow marine environment. A distinctive feature of the Erebus beds is their radiometric signature that reflects the potassic nature of the unit.

The western contact of the Erebus beds against the Mount Mount Alma Formation is in part a north-west trending fault or shear zone, with northerly trending splays. Several old workings and one current gold mining operation are located along these structures.

Geochemical data supports the interpretation that the Erebus REU was formed in an ocean island arc environment. Contacts of these early to middle Devonian units with the Upper Devonian to Carboniferous arc/forearc basin sequence are largely faulted, but an unconformable relationship has been established locally.

Craigilee REU

The Craigilee REU extends from Mount Cassidy on the Rookwood sheet to near Ridgelands. This REU, comprising the Craigilee beds, consists of volcanic rocks ranging from andesite to dacite, volcaniclastic breccia, sandstone, siltstone, mudstone, minor limestone and polymictic conglomerate. The Craiglee beds have been subdivided into a lower felsic series of sandstones, siltstones, granular conglomerates, limestone, and minor volcanic rocks; a middle series dominated by porphyritic andesite to dacite flows and local flow breccias; and an upper series comprising sandstone, breccia, siltstone and mudstone, and minor conglomerate and limestone. Sandstone and breccia in the upper series were derived mainly from intermediate volcanics, with a dominantly felsic source towards the top. Although the sequence extends lower than the known Capella Creek Group, the base of which is not preserved, some degree of lithological correlation is possible between the Craigilee beds and the Capella Creek Group. Whilst the Mount Morgan and Craigilee REUs are both oceanic island arc settings, basalt geochemistry suggests significant differences between the two REUs. The Mount Morgan REU basalts are distinguished by strongly depleted high field strength elements and high Ti/Zr and Sc/Y ratios, indicating a primative oceanic island arc with an associated active backarc basin (Murray & Blake, submitted).

Mount Morgan REU

The Mount Morgan REU is a belt of rocks extending south-south-east from around Mount Morgan along the Dee Range. The REU includes the **Capella Creek Group** and the **Marble Waterhole beds** and is dominantly volcaniclastic but includes some primary volcanic rocks such as lavas, peperites, volcanic bomb breccias, and accretionary lapilli tuffs. Deposition of the Mount Morgan REU began in the Late Silurian and was sourced from dacitic and rhyolitic volcanics with lesser amounts of andesitic and basaltic volcanics. In the late Middle Devonian the depositional setting changed to primarily andesitic and basaltic volcanism but reverted to dacitic and rhyolitic volcanism towards the top of the REU sequence. In the Mount Morgan area, Middle Devonian granitoids ranging from gabbro to tonalite intrude the sequence. Geochemical investigations (Messenger, 1996) of the felsic rocks of the Mount Morgan Tonalite have been interpreted as being derived by partial melting of a basaltic andesite. The felsic volcanics and intrusives within the REU are considered to have been sourced from fractionated components of a juvenile ocean island arc, derived from a depleted mantle source, results that are similar to the modern south-west Pacific ocean island arcs (Murray & Blake, submitted). The Mount Morgan REU contains relatively common fossiliferous limestone, and some of the sandstones within the sequence are fossiliferous. There is no evidence suggesting that the fossils have been transported and the REU is interpreted to have been deposited in a shallow marine environment.

The Capella Creek Group from the base to the top, consists of:

The **Mount Dick beds**, which are dominated by silicified siltstone with minor very fine to very coarse-grained sandstone sourced from rhyolitic volcanic rocks. This unit is usually strongly hornfelsed by the Bajool Quartz Diorite to the east.

The **Mount Warner Volcanics**, which are dominated by sandstone sourced from rhyolitic to dacitic volcanics, accompanied by silicified rhyolite, chert, jasper, peperite, and minor andesitic breccia and limestone. This middle, more siliceous unit includes the host rocks of the Mount Morgan orebody, and can be traced south-east along the Dee Range, where small stratabound base metal sulphide deposits occur.

The **Raspberry Creek Formation**, a unit of sandstone, conglomerate, breccia, and minor limestone. In this upper sequence, the clastic rocks are mainly sourced from andesitic and basaltic volcanics, with an increasing felsic component towards the top, locally mapped out as the Ginger Creek member.

Fossils from the Capella Creek Group are confined to the Middle Devonian. The Capella Creek Group was intruded by the Mount Morgan Tonalite before deposition of the overlying Upper Devonian strata. Geochemically, volcanics in the Capella Creek Group are indistinguishable from the Mount Morgan Tonalite and are typical of rocks from oceanic island arcs.

The Marble Waterhole beds may be correlatives of the felsic part of the upper unit of the Capella Creek Group (Ginger Creek member). The Marble Waterhole beds contain large areas of fossiliferous limestone, but also include quartz-bearing feldspatholithic sandstone, granule to pebble dacitic breccia/conglomerate, and dacitic to rhyolitic tuff/ignimbrite. The limestones contain abundant corals which, combined with conodont work, have returned a very precise age in the early to middle Givetian (late Middle Devonian). The Allen Creek or Mount Kroombit copper mine a skarn occurrence is hosted by the Marble Waterhole beds, as are two possible volcanic-hosted massive sulphide occurrences.

Late Devonian to Late Carboniferous — Arc/Forearc Basin

Three parallel belts of contrasting stratigraphic and structural style can be recognised in the Yarrol Province, and have been interpreted as an accretionary wedge in the east, a forearc basin in the centre, and a volcanic arc in the west (Murray & others, 1987). The forearc basin is separated from the accretionary wedge by the Yarrol Fault System, which is marked in part by serpentinite lenses. The serpentinites are probably fragments of early Palaeozoic ocean floor.

Upper Devonian and Lower Carboniferous rocks form part of an arc/forearc basin assemblage related to what is thought to be a west-dipping subduction zone. This sequence shows considerable variation across the regional north-north-west trend reflecting the shape of the basin which overall deepened to the east, the proximity to the active volcanic source in the west, and changes in the composition and location of the volcanic arc with time. In Devonian time at least, the arc is interpreted to have been located within the outcrop area of these units, and was mainly submarine.

The forearc basin sequence consists of volcaniclastic sediments deposited on a marine shelf which shallowed to the west with time, some primary volcanics that increased proportionately towards the western arc, and widespread oolitic limestone beds. The sequence consists of lateral facies equivalents in the Upper Devonian (**Lochenbar Formation, Mount Hoopbound Formation, Alma Formation, Balaclava Formation, Three Moon Conglomerate, Channer Creek beds, Yarwun Beds**) overlain by a single Early Carboniferous unit, the **Rockhampton Group**. The **Lorray Formation**, overlying the Rockhampton Group and extending into the Upper Carboniferous, is predominantly a felsic-rich clastic sedimentary unit that marks the end of the forearc basin assemblage.

These different formations can be grouped and interpreted into a single volcanic arc setting but are discussed here as three REUs: Hoopbound REU, comprising units proximal to a volcanic arc (Mount Hoopbound Formation, Lochenbar beds, Balaclava Formation, Three Moon Conglomerate); Alma REU, comprising units distal to a volcanic arc (Mount Alma Formation, Yarwun beds); and the Rockhampton REU, representing deposition in the forearc basin (Rockhamton Group, Lorray Formation). Most areas can be placed with relative ease into one of these REUs, but in some areas the proximal units grade laterally into the distal units and the boundary between the two categories is arbitrary (Figure 4 — Proximal vs Distal Arc/Forearc).

Hoopbound REU

The Hoopbound REU consists of coarse-grained sandstones and conglomerates with some volcanics (lava flows, pillow basalts, hyaloclastites, ignimbrites, and accretionary lapilli tuffs). In the early Late Devonian (Frasnian) these volcanics were primarily basalts and andesites (eg Mount Hoopbound and Lochenbar Formations), but dacitic and rhyolitic volcanism was still common (eg Balaclava Formation). In the late Devonian (Famennian), dacitic and rhyolitic volcanism became increasingly more common, and eventually dominated the Yarrol Province.

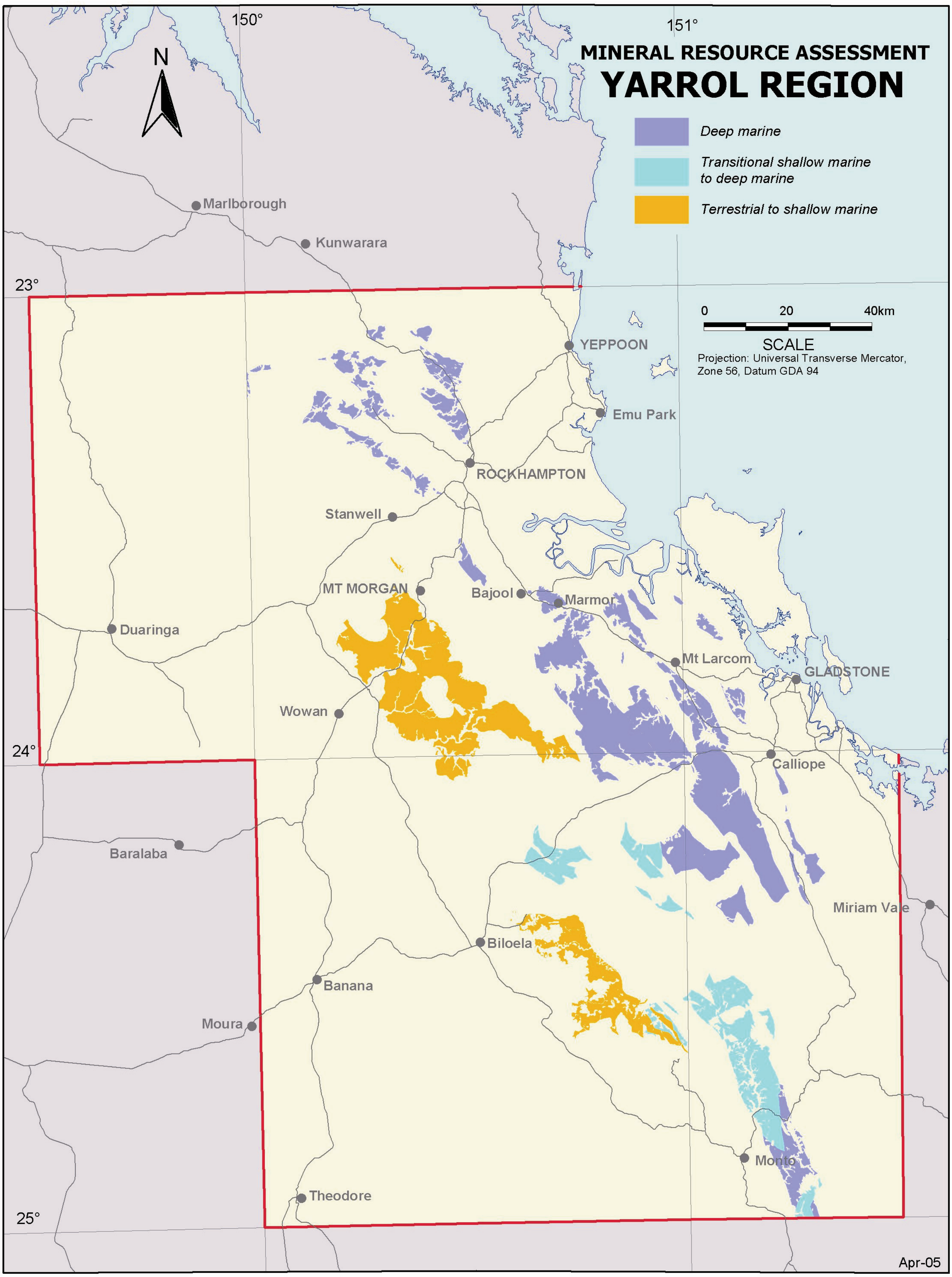
The **Mount Hoopbound** and **Lochenbar Formations** are similar in rock type and deposition environment being dominated by granule to cobble sized andesitic epiclastic rocks with lesser thicknesses of fine-grained sediments, basaltic to andesitic lava, and a few limestone occurrences. Basaltic to andesitic lavas are common in the Mount Hoopbound Formation and are a widely distributed but a minor component of the Lochenbar Formation. The base of the Mount Hoopbound Formation is a polymictic conglomerate containing clasts derived from the underlying Mount Morgan Trondhjemite and Capella Creek Group. The base of the Lochenbar is not exposed. Both the Mount Hoopbound Formation and the Lochenbar Formation are of Late Devonian (Frasnian and Famennian) age. Geochemical analyses of volcanic samples from the Lochenbar Formation are consistent with formation in an evolved oceanic island arc setting or at the continent-ocean boundary in a transitional arc (Murray & Blake, submitted).

The **Balaclava Formation** is partly a time equivalent of, and partly overlies, the Mount Hoopbound Formation. Typical rock types in the Balaclava Formation include siltstone, feldspatholithic to lithofeldspathic arenite, rhyolitic ignimbrite and accretionary lapilli tuff, and granule to pebble volcaniclastic conglomerate and breccia derived from dominantly rhyolitic to dacitic volcanic rocks. A less common rock type is an epiclastic andesitic breccia/conglomerate which appears similar to rocks of the Mount Hoopbound Formation, but differs in containing free quartz and few, if any, of the hematised lithic fragments which characterise the Mount Hoopbound Formation. Rocks of the Balaclava Formation are typically feldspathic, contain abundant volcanic quartz, and return a moderately high radiometric response in all three channels. This contrasts with the very low response of the dominantly andesitic volcaniclastic units of the Mount Hoopbound Formation and the upper part of the Capella Creek Group.

In the Hoopbound REU there is some evidence for terrestrial deposition such as welded ignimbrites, but the common occurrence of marine fossils and presence of ripple marks suggests that it was dominantly deposited in a shallow marine environment. Geochemical and facies analysis of the Frasnian volcanics indicate that they exhibit close affinities to either continental or oceanic island arc setting.

A deeper water marine environment is represented by the **Three Moon Conglomerate** and the **Channer Creek beds**. The Three Moon Conglomerate contains fine to coarse purplish sandstone, poorly sorted conglomerate, siltstone, minor andesite and pillow basalt. Conglomerates in the unit contain rip-up clasts but are dominated by subangular to rounded purple hematised andesitic to dacitic volcanic fragments and lithic sandstone blocks. Sharp erosive contacts have been observed at the base of these conglomerates. The unit is less felsic than the Balaclava Formation and possesses a correspondingly diminished radiometric signal, with a low response in all channels. It contains more abundant coarse-grained facies than the Mount Mount Alma Formation and is distinguished from that unit by the presence of purple hematised clasts in the sandstones and conglomerates. The consistent presence of minor quartz and the presence of finer grained graded facies and rip-up clast conglomerate can be used to distinguish the unit from the Lochenbar and Hoopbound Formations. The unit is a partial time equivalent of the Mount Alma and Balaclava Formations and is considered to overlie the Lochenbar Formation and underlie the Rockhampton Group. Geochemical analyses of volcanics from the Three Moon Conglomerate show spreading backarc characteristics. The Channer Creek beds are predominantly composed of fine to coarse lithic sandstone and granular to pebble conglomerate. They also contain some siliceous argillite. The lithic sandstone is composed

Figure 04 - Proximal vs Distal Arc/Forearc



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almost entirely of andesite and is extensively distrupted by faulting (Dear & others, 1971). Early upper Devonian fossil corals have been identified in the calcareous conglomerate of the Channer Creek beds.

Alma REU

The sequences distal to the volcanic arc are commonly dominated by thinly interbedded siltstone and fine-grained sandstone, with granule to pebble conglomerate that contain common rip-up clasts. These rocks are virtually barren of marine macrofossils, with only rare specimens found in the rip-up clast conglomerates. Siliceous microfossils thought to be radiolarians are common in the siltstone and fine-grained sandstone. These rocks are interpreted to have been deposited in a deep marine environment equivalent to mid-outer shelf depths.

The **Mount Mount Alma Formation** is a very extensive unit in the eastern part of the forearc basin sequence. The fine-grained sandstone and siltstone of this unit are usually rhythmically interbedded in places, and commonly possess a weak cleavage which is parallel to that in the Erebus beds. Ripple laminations and other current formed sedimentary structures are rare, but soft sediment deformation features are common. Conglomerates and very coarse-grained sandstones are a minor component, but are distinctive because they almost always contain rip up clasts. Limestones at the base of the sequence in the Mount Holly region have yielded upper Lower Devonian to lower Middle Devonian conodonts and corals. However, sandstone units within the sequence contain Upper Devonian brachiopods, and thin limestone beds sampled from within the Mount Mount Alma Formation have returned Upper Devonian conodonts. The limestones at the base of the sequence in the Mount Holly region are believed to be allochthonous and sourced from the Erebus beds. The contact between the Erebus beds and the Mount Alma Formation, where it is not faulted, is interpreted as an unconformity which is equivalent to the intra-Devonian unconformity between the Capella Creek Group and the Mount Hoopbound Formation in the Mount Morgan area.

The **Yarwun beds** have many similarities with the Mount Mount Alma Formation but appear to have been sourced from more felsic volcanics. Conglomerates often dominate the base of the formation and it forms a hilly topography and is usually is well exposed. The rest of the sequence contains a large proportion of siltstone and fine-grained sandstone that crops out poorly, and forms only low hills. Because of similarities with the Mount Alma Formation the Yarwun beds are interpreted to have been deposited in a deep marine environment.

Rockhampton REU

In the Early Carboniferous there was a change with significant deposition in the forearc basin to the east of the volcanic arc. The **Rockhampton Group** (Lion Creek Limestone, Malchi Formation and Cargoogie Oolite Member, Gudman Oolite and undifferentiated Rockhampton Group) consists of a suite of rocks ranging in age from Tournaisian to Visean (Early Carboniferous), and includes oolitic limestone, calcareous ooid-rich and fossiliferous sandstone, siltstone, mudstone, polymictic conglomerate (locally containing intraformational rip-up clasts) and minor rhyolitic ignimbrite. The dominant rock types are siliceous mudstone and siltstone, which differs from the fissile, rhythmically interbedded siltstone and mudstone of the Mount Alma Formation. The sediments of the Rockhampton Group are generally richer in quartz and felsic volcanic clasts than underlying units, and give a higher radiometric response (with the exception of parts of the Balaclava Formation). The increased content of radiogenic elements in the Rockhampton Group indicates a regional change in the composition of volcaniclastic sediments, and hence of the source volcanics, which became progressively more felsic with time. This trend is continued later in the Carboniferous, with another marked regional increase in radiometric response of mid-Carboniferous to Lower Permian sedimentary units.

The **Lorray Formation** is a mid-Carboniferous to Upper Carboniferous marine succession that includes quartzose feldspatholithic sandstone, siltstone, mudstone, polymictic conglomerate and minor limestone. Bryozoan mudstone is locally dominant. The marked regional increase in radiometric response of the Lorray Formation compared to older strata can be directly correlated with an abrupt increase in the amount of granitic detritus (and accompanying felsic volcanic clasts) within the sediments. It is possible that this resulted from the dissection of the plutonic core of the volcanic arc to the west.

Devonian to Carboniferous — Accretionary Wedge

Rocks of the **Curtis Island Group** and the **Marlborough Metamorphics**, which are interpreted as an accretionary wedge assemblage coeval with the Upper Devonian to Carboniferous arc/forearc basin sequence to the west, form the region east of the Yarrol Fault. These rocks comprise the Curtis Island REU.

Curtis Island REU

Although structurally complex, the accretionary wedge has been subdivided into three formations collectively termed the Curtis Island Group (Kirkegaard & others, 1970). The westernmost **Doonside Formation** comprises radiolarian jasper and chert, spilitic pillow basalt, argillite, and rare limestone lenses. To the east it grades into interbedded volcaniclastic greywacke and argillite with chert lenses of the **Wandilla Formatio**n. The Wandilla Formation includes a characteristic layer of oolitic greywacke beds, which persists for the entire strike length of the accretionary wedge assemblage along the New England Orogen. The ooliths are sourced from Lower Carboniferous limestones within the forearc basin sequence to the west, and, together with sparse fossil fragments concentrated at the base of graded beds, provide an age for this part of the accretionary wedge (Fleming & others, 1975). The easternmost and presumably youngest part of the accretionary wedge sequence, the **Shoalwater Formation**, is anomalous in that it consists exclusively of interbedded quartzose sandstone and black-thinly bedded argillite. Its anomalous composition in the context of the accretionary wedge assemblage has led to suggestions that it is an exotic terrane. However, an exotic origin appears to be precluded by the gradational contact between the Wandilla and Shoalwater Formations in their type area within the Shoalwater Bay military training area, where volcaniclastic greywackes are interbedded with quartzose sandstones (Kirkegaard & others, 1970).

Although the age limits of the accretionary wedge in central Queensland are poorly constrained, radiolarian faunas from elsewhere in the New England Orogen suggest that the Doonside and Wandilla Formations accumulated mainly in Early Carboniferous time. Locally, the banded jaspers of the Doonside Formation appear to be older, where conodonts of Late Silurian to Middle Devonian were reported by Fergusson & others (1993), but are probably no older than Devonian. No fossils are known from the Shoalwater Formation. However, the unit may be a correlative of the Good Night beds west of Maryborough, which have been assigned a Late Carboniferous age based on conodont faunas in small recrystallised limestone lenses.

Interbedded with the cherts of the Doonside Formation on the Rockhampton sheet area are basic to intermediate lavas and tuffs, some acid tuff, agglomerate, mudstone and limestone. Basic volcanics have also been described near the western margin of the Doonside Formation on the Gladstone sheet by Donchak & Holmes (1991). These rocks have been mapped out as an informal member of the Doonside Formation, the Balnagowan Volcanic Member. Willmott & others (1986), however, have suggested that rocks mapped as the Balnagowan Volcanic member might represent part of the Calliope beds or the Erebus beds. The unit, being both problematic and of small geographical extent, has been omitted from the current analysis.

The **Marlborough metamorphics** are included here as part of the Devonian-Carboniferous accretionary wedge. Bruce & others (2000) discuss the Marlborough terrane as a fault bounded, near horizontal, out of sequence thin-skinned nappe sheet, consisting of thrust imbricated slices of an ultramafic-mafic complex (Neoproterozoic serpentinite, serpentinised harzburgite, altered gabbro), upper and lower greenschist facies metasedimentary units (quartz-feldspar-mica schist, banded quartzite — Marlborough Metamorphics), and lower amphibolite facies S-type metagranite and metabasite. The metasedimentary units are described by Holcombe & others (1997b) as being similar to units of the accretionary wedge. Whilst these quartzite units are likely to be equivalents of the accretionary wedge, the presence of metamorphosed well-bedded limestones not evident elsewhere in the accetionary wedge suggest that the Marlborough Metamorphics may be a composite package and include portions of other units. Basalt and dolerite dykes and blocks within the Marlborough Metamorphics have been dated at 380±19Ma (Bruce & Niu, 2000).

Geochemical analyses indicate similarities of the basalts of the Lochenbar Formation to tholeiites from the Marlborough Metamorphics suggesting similar mantle sources and the location of the metamorphics close to its present position in Late Devonian time (Murray & Blake, submitted).

Late Carboniferous–Early Permian — Transitional Arc/Extensional Volcanics

The volcanic and granitic rocks of the Auburn Arch were originally interpreted as the continental margin magmatic arc associated with the Upper Devonian–Carboniferous accretionary wedge and forearc basin (Day & others, 1978; Murray & others, 1987). However, more recent work indicates that the Late Devonian arc was not in this position (Murray & Blake, submitted). Currently, there are two models for the Auburn Arch: Holcombe & others (1997b) consider that "the Connors-Auburn Province represents an extensional event that is not necessarily related in any way to active subduction" whilst Murray (2003) regards the mid-Carboniferous granites of the Auburn Arch as the final products of subduction-related magmatism and that both granites and volcanics span the transition from arc to extensional magmatism.

The radiometric signature of the Yarrol Province fill indicates a change to more felsic volcanism at the beginning of the Carboniferous. However, although the volcanics of the Auburn Arch are of rhyolitic to dacitic composition, recent dating shows that they are of Late Carboniferous rather than Early Carboniferous age. There are no definite rocks of the Early Carboniferous magmatic arc within the Auburn Arch.

Camboon REU

The Camboon REU consists of the **Torsdale Volcanics, Camboon Volcanics, Mount Benmore Volcanics** and **Leura Volcanics**.

The **Torsdale Volcanics** crop out at the western extent of the Yarrol assessment area. This unit consists of ignimbrite, rhyolitic and dacitic lavas, pyroclastics and interbedded trachytic and andesitic volcanics, lithic sandstone, siltstone and conglomerate.

The Early Permian **Camboon Volcanics** overlie granites and probably disconformably, the Torsdale Volcanics of the Auburn Arch. The Camboon Volcanics consists mostly of basaltic to dacitic lavas and volcaniclastic rocks, including epiclastic sandstone and conglomerates as well as probable pyroclastics. At some localities, the base of the Camboon Volcanics is marked by conglomerate, the Mount Bulgi Conglomerate Member. The conglomerate is derived mainly from the Torsdale Volcanics, but also includes clasts of granite that intrudes the Torsdale Volcanics. Generally speaking, however, it is difficult to distinguish between the Camboon and Torsdale Volcanics, as similar rocks occur in both, although in different proportions. Dating of rocks mapped as Camboon Volcanics suggests that the break between the two units is relatively short (possibly 5Ma or less) and that volcanism in some areas was relatively continuous (Withnall & others, in preparation) and breaks such as that of the Mount Bulgi Conglomerate member may not be regionally significant.

The Camboon Volcanics crop out extensively in the assessment area in the north-eastern part of the Theodore sheet and the north-western part of the Scoria sheet. These rocks flank the eastern side of the Torsdale Volcanics and Carboniferous granitoids and are folded with the overlying Back Creek Group in the Prospect Creek Anticline. Farther east they occur with the Back Creek Group in a complex zone of thrusting and folding. Here the unit mostly comprises aphyric to porphyritic basalt to andesite lava and volcaniclastic rudite and arenite. The basalts are commonly amygdaloidal with quartz-filled amygdales that locally contain chalcopyrite. Specks of native copper can also be observed in the groundmass of the basalt in places. Felsic rocks also occur within the dominantly mafic succession and are primarily volcaniclastic and probably include some ignimbrite. In the area north of Banana, the Camboon Volcanics locally have zones of alteration, brecciation and epithermal-style quartz veining and contain gold mineralisation. Potassic anomalies in the airborne radiometrics in this area are partly due to alteration, but also appear to include small rhyolite intrusions.

The Camboon Volcanics are interpreted as being erupted in a non-marine, largely subaerial environment, with clastic rocks being deposited in local fluvial or lacustrine environments or by mass flow processes within the volcanic terrain. The Mount Bulgi Conglomerate member may represent alluvial fan systems developed adjacent to the older volcanic terrain of the Torsdale Volcanics prior to the renewed onset of volcanism. This conglomerate unit is considered to be an equivalent to the Youlambie Conglomerate, with both conglomerate units being of similar composition, with abundant felsic volcanic and granitic clasts.The **Leura Volcanics** are a sequence of mainly felsic to intermediate volcanics and epiclastic sedimentary rocks that occur in the assessment area as the core of the Leura Anticlinorium and as partly fault-bounded slices in the Gogango Overfolded Zone in the Rookwood sheet. Here the rocks are partly folded with and thrust against the Mount Benmore Volcanics and Back Creek Group. The unit in the anticlinorium is composed of a mixture of lavas and volcaniclastics (arenite, rudite and possible ignibrite). The lavas are generally aphyric to porphyritic trachyandesite to andesite. The volcaniclastic rocks are very poorly-sorted, thick-bedded and massive. The rudites contain angular to sub-angular felsic to intermediate, porphyritic to aphyric volcanic clasts in a fine to very coarse-grained matrix of crystal fragments, lithic clasts and recrystallised ash or glass. The rudites are interbedded with arenites similar in composition to the matrix. Some of the arenites may be ignimbrites, however, any igneous foliation is difficult to distinguish from a tectonic foliation that becomes more common and stronger moving to the east. Alteration is common throughout the volcanics. In the Gogango Overfolded Zone, west of Melaleuca Creek, greenschist facies metamorphism is associated with the deformation and the matrix of many of the clastic rocks contains abundant fine-grained chlorite and muscovite. The relationship of the Leura Volcanics in this area to the surrounding more mafic volcanics of the Mount Benmore Volcanics is uncertain although a hiatus accompanied by erosion is probably likely between the units. Further erosion is indicated post-dating the Mount Benmore Volcanics with the Back Creek Group directly overlying the Leura Volcanics in some places. Results of age dating (SHRIMP) and stratigraphic relationships (Withnall & others, in preparation) suggest that the Leura Volcanics are probably mainly latest Carboniferous, possibly extending into the Early Permian. The Leura Volcanics formed in a subaerial environment, being dominated by lavas, some ignimbrites, and coase-grained, mostly poorly-sorted volcaniclastics. The volcaniclastic rocks may have been formed by fluvial processes and mass flows.

The **Mount Benmore Volcanics**, which crop out in the westernmost part of the Rookwood sheet, are partly equivalent to the Camboon Volcanics in the Auburn Arch (ie the upper part of Cycle 3B — Dear, 1994). These volcanics, which include the Cerberus Dacite Member, are dominated by lavas with subordinate volcaniclastics that are of variable composition, mostly basaltic andesite or basalt and some dacite and andesite. The rocks in general are dark greenish-grey and generally contain sparse phenocrysts of ophitic clinopyroxene and plagioclase. Some of the rocks are conspicuously amygdaloidal and some show partial flow alignment of the plagioclase laths. This unit is considered to be largely subaerial. Some autoclastic breccia textures may be due to quench fragmentation, but no definite pillow lavas have been observed. The volcaniclastic rocks are likely to have been formed by a variety of subaerial processes involving mass flows and fluvial traction currents. Local fine-grained sedimentary rocks are considered to represent lacustrine or fluvial overbank deposits.

The precise age of the Mount Benmore Volcanics is uncertain, but as they are younger than the Coppermine Andesite (~296Ma) they are assigned an Early Permian age (Withnall & others, in preparation).

Late Carboniferous to Cretaceous — Developing Basin

Towards the end of the Late Carboniferous, the tectonic setting of the Yarrol Province changed from a compressional regime related to active subduction to regional extension (Hutton & others, 1999). The upper age limit of the forearc basin fill, and of the Late Devonian–Carboniferous convergent margin tectonism, is unclear. Dates from arc volcanics and granitoids west of the Yarrol Province suggest that westward subduction beneath the continental margin continued through much if not all of the Late Carboniferous. Lower Permian strata, which overlie the Upper Devonian–Carboniferous forearc basin sequence have recently been interpreted as the fill of a series of extensional basins which developed at the same time as the Bowen Basin to the west (Fielding & others, 1997). This interpretation is consistent with the fact that many of the Permian outcrops overlie Lower Carboniferous or older rocks, implying removal or non-deposition of a substantial part of the stratigraphic section. In contrast to this model of extensional basin formation at the beginning of the Permian is the existence of continuous and uniform Carboniferous–Permian marine sequences in some areas in the southern part of the Yarrol Province, for example in the Yarrol syncline. The presence of continuous Carboniferous–Permian sequences suggests that the deformation did not occur in the south or that it occurred later or was expressed differently in the southern part of the Province. The affiliation of undifferentiated Permian sediments (Pu) remains unclear.

Upper Carboniferous to Cretaceous rock units interpreted as part of a developing basin setting have been grouped into the Youlambie, Dinner Creek, Muncon and Precipice REUs. The Youlambie REU includes Upper Carboniferous to Upper Permian units, the **Youlambie Conglomerate, Berserker Group, Yarrol Formation, Owl Gully Volcanics, Yaparaba Volcanics, Rookwood Volcanics**, the basal sequence of the **Back Creek Group**, the **Smoky beds** and the **Woolein Formation**. This REU contains diverse and locally to regionally identifiable units that represent the initiation of extension in the area. The Barfield REU includes the **Oxtrack Formation, Barfield Formation** and **undifferentiated Back Creek Group strata**. This REU represents a brief period of basin subsidence during middle Permian times. The Dinner Creek REU includes the **Warminster Formation, Moah Creek beds, Dinner Creek Conglomerate** and the upper sequence of the **Back Creek Group (Flat Top and Boomer Formations)**. This REU represents foreland phases of basin development. The Muncon REU groups Triassic continental volcanics including the **Winterbourne Volcanics, Dooloo Tops Volcanics, Muncon Volcanics, Native Cat Andesite** and unnamed volcanics on the Calliope sheet and volcanics that occur at the base of the Upper Triassic **Callide Coal Measures**. These represent a transition from subduction-related magmatism to backarc extension. The Precipice REU consists of latest Triassic to Cretaceous sediments, and represents the succeeding thermal sag phase of basin development. This group is characterised by more extensive deposition of shallow marine sandstone, mudstone, and subordinate carbonates. This REU includes the **Annie Creek beds, Precipice Sandstone, Evergreen Formation, Hutton Sandstone**, and **Mulgildie Coal Measures**.

Youlambie REU — Extensional Basin

The Youlambie REU includes both Latest Carboniferous(?) to Early Permian age marine and continental deposits that have recently been interpreted as the fill of a series of extensional backarc basins.

The **Youlambie Conglomerate** is a dominantly continental unit, which maybe partly equivalent to the upper section of the Lorray Formation. In the south of the Yarrol Province the two units are separated; the marine Lorray Formation occurring to the east of the non-marine Youlambie Conglomerate, which disconformably overlies strata of Early Carboniferous and Late Devonian age. However, in the area west and north-west of Rockhampton, the Youlambie Conglomerate has been mapped in sequence with and overlying the Lorray Formation. The Youlambie Conglomerate consists of boulder to pebble conglomerate, conglomeratic mudstone, quartzose feldspatholithic and lithic sandstone, siltstone, and acid volcanics. The conglomerate is polymictic, with clasts of acid and intermediate volcanics, granite, aplite, quartz porphyry, and indurated siltstone. Sparse Lower Permian fossils are present in the unit, but its base could extend into the Carboniferous.

The Early Permian **Rookwood Volcanics**, which host the Cu-Zn volcanogenic massive sulphide deposits at Develin Creek, occur as a number of discrete blocks. The unit consists dominantly of basalt and high-level mafic intrusives, with minor rhyodacite lava, volcanilithic breccia and sandstone, and mudstone. Pillows, autobreccias, and peperites are relatively common in the northern blocks whereas the southern exposures are dominantly massive. Geochemical analyses indicate that the basalt has MORB-like affinities (O'Connell, 1995). Volcaniclastic sediments are more common in the north. Thin to laminated carbonaceous mudstones which contain trace fossils indicative of shelfal depths, appear to be hemipelagic and low concentration turbidite deposits. The overall depositional environment is inferred to be shelfal, below storm wave base (Yarrol Project Team, 1997). The disconnected outcrop pattern of the Rookwood Volcanics can be attributed to thrust deformation in the Hunter Bowen orogeny (Holcombe & others, 1997a). In this model sequences including parts of the Rookwood Volcanics were thrust from the east into their present position, locally overlying stratigraphically higher Bowen Basin sediments. The Rookwood Volcanics are similar in many respects to the Permian Berserker Group, and at their closest point the two units are separated by only ~30km. However, they differ significantly in the composition of the volcanic rocks, the Berserker Group being dominantly felsic.

The **Berserker Group** comprises broadly folded sediments and acid to intermediate volcanics which form a north-north-west trending belt west of the Yarrol Fault System, both north and south of the Fitzroy River. Laminated siltstones and fine-grained sandstones occur around Lakes Creek, and coarser volcaniclastic sediments and siltstone, including fossiliferous calcareous sandstone, form a belt just west of the Yarrol Fault System. Mixed sedimentary and volcanic sequences, comprising sandstones, siltstones and felsic to intermediate pyroclastics, occupy the central part of the area and are host to the Mount Chalmers volcanogenic massive sulphide deposit. Much of the high country from Mount Archer to Mount Nicholson consists of intrusive to extrusive domes of rhyolitic and dacitic composition. Similar rhyolite and dacite occur along the Flat Top Range and in the Mount Kilner–Broadmount area. Marine fossils correlative with faunas in the Early Permian Buffel Formation of the Bowen Basin have been identified at several localities, and a younger fauna equivalent to that in the Ingelara and Barfield Formations of the Bowen Basin has been collected from conglomerate 800m north of Mount Chalmers. The Berserker Group is bounded by the Yarrol Fault System in the east and the Alton Downs Fault in the west.

The **Yarrol Formation** comprises limestone, siltstone, and lithic sandstone, and is located in the Yarrol Syncline south-east of Monto. The limestones are fossil-rich and grade into calcareous siltstone and fine-grained sandstones. Andesitic lavas similar to those of the overlying Owl Gully Volcanics are interbedded towards the top of the Yarrol Formation in the Spring Creek area. As originally defined by Dear & others (1971) the Yarrol Formation outcrops on both limbs of the syncline, however recent interpretation of radiometric data has led to the subdivision of the formation into Yarrol Formation and undifferentiated rocks.

The **Owl Gully Volcanics** consist of andesitic to basaltic flows and pyroclastics, interbedded siltstone and minor lithic sandstone. Andesitic lava is the dominant rock type. The lavas are porphyritic, with phenocrysts of plagioclase and augite in a fine-grained groundmass of similar composition. No acid volcanics are known in the unit. Interbedded siltstones are black and have an 'ashy' appearance when weathered. The siltstones are calcareous when fresh. The volcanics conformably overlie the Yarrol Formation in the Yarrol Syncline, the two units grading into each other. Both the Yarrol Formation and the Owl Gully Volcanics contain marine faunas of Early Permian age.

The **Yaparabara Volcanics** consist of basaltic and andesitic to dacitic lavas, massive and poorly sorted volcaniclastic mafic and rarely felsic rocks, and in scattered localities, well-bedded volcanilithic sandstone and siltstone crop out. In contrast to the Camboon Volcanics located west of the Grevillea Thrust the Yaparabara Volcanics are generally not cleaved.

These volcanics are considered to be of probable Early Permian age, like the Owl Gully Volcanics, but may possibly extend into the Late Carboniferous like the Camboon Volcanics.

It is not clear from the available data whether deposition occurred in a subaerial or subaqueous environment, although the presence of bryozoan fossils suggest a predominantly marine environment.

The lower **Back Greek Group, Buffel Formation**, outcrops poorly and discontinuously and is best developed south-west of Biloela where it forms low limestone ridges. The unit consists primarily of a grey bioclastic limestone and dark blue to brown silty limestone, siltstone and minor sandstone. Sandstone from the Buffel formation has been described as medium to coarse-grained with a clayey matrix and containing pebbles of quartz and tuffaceous siltstone and traces of mica. The siltstone is tuffaceous and contains minor mica and is slightly carbonaceous. The limestone contains abundant shell and crinoid fragments. In the Prospect Creek Anticline, the base of the Buffel Formation is marked by a calcareous conglomerate that grades along strike through pebbly limestone into limestone. Pebbles in the conglomerate appear to have been derived from the underlying Camboon Volcanics.

Deposition of the Buffel Formation represents a major Early Permian marine transgression also reflected by the Yarrol Formation. The patchy distribution of the Buffel Formation could be due to its deposition in small sub-basins during the early extensional phase of the Bowen Basin evolution (Draper, 1988). In the Rannes area, rocks of the lacustrine Woolein beds overlie and possibly interfinger with the Camboon Volcanics in a sub-basin that may have formed during the same event.

In the south-eastern part of the Bowen basin faunal evidence shows a disconformity between the Buffel Formation and Oxtrack Formation, however, in the northern part of the Bowen Basin, deposition appears to have been continuous.

The **Smoky beds** are almost exclusively conglomerates, breccias and coarse sandstones composed of andesitic volcanic clasts, which are intruded by dykes and small irregular bodies of andesitic material that may represent the source of the volcanic clasts. The unit is readily recognised in composite radiometric images by a much lower radiometric response than the surrounding Youlambie Conglomerate, indicating a marked change in provenance. The Smoky beds appear to conformably overlie the Youlambie Conglomerate, but in one locality ~30km north of Biloela, the contact is marked by a fossiliferous calcareous unit that resembles the Yarrol Formation.

The **Woolein Formation** is overlain by the Back Creek Group and overlies the Camboon Volcanics. It consists of khaki-coloured weathered and cleaved siltstone and fine-grained sandstone. The radiometric response is similar to the underlying Camboon Volcanics, which may have been the main provenance of the sediments. The unit is therefore likely to be of Early Permian age. The dominance of fine-grained sediments, the absence of both marine body and trace fossils in the Woolein Formation, and its restricted extent is consistent with deposition in a largely lacustrine environment in a rift setting during the early extensional phase of the Bowen Basin.

Barfield REU — Basin Subsidence

During middle Permian times a short-lived subsidence event occurred in the Bowen Basin (Fielding & others, 2000). During this time carbonates accumulated over some slowly subsiding basement highs to form limestones such as the Oxtrack Formation, and deltaic and coastal clastic sediments continued to accumulate further west. In the early Late Permian mainly fine-grained, off-shore marine sediments were deposited to form the Barfield Formation, undifferentiated Back Creek Group strata, Boomer Formation and Moah Creek beds.

The Oxtrack Formation is characterised by grey bioclastic limestone, fossiliferous silty limestone, siltstone, mudstone and lithic sandstone. The limestones are crowded with large crinoid stems and numerous brachiopods, bryozoans, bivalves and corals. Some or all of the rocks mapped in the Gogango Overfolded Zone as Subunit Pbz of the Back Creek Group could be equivalents of the Oxtrack Formation

The **Oxtrack Formation** is overlain conformably by the Barfield Formation, and, in the absence of limestone, it is difficult in some places to distinguish them. The Oxtrack Formation, used in the sense of Dear & others (1971) is separated from the Buffel Formation by a significant faunal break.

The **Barfield Formation** is poorly exposed and forms a belt of low-lying black soil country between ridges of the Oxtrack and Flat Top Formations. Outcrops are confined to gullies and areas of sheet wash, but concretions are common in the soil. The Barfield Formation is characterised by massive mudstone and subordinate siltstone, sandstone, tuff and conglomeratic mudstone and limestone. Glendonites occur in some concretions, and towards the top of the formation, they also contain abundant fossils, particularly the corals *Cladochonus* and *Gertholites*. Some of the beds are burrowed.

East of Banana, the Cottenham Sandstone member is exposed forming strike ridges. Much of the undivided Back Creek Group studied in the GOZ is probably equivalent to the Barfield Formation. The Barfield Formation conformably overlies the Oxtrack Formation, or in its absence, disconformably overlies either the Buffel Formation or Camboon Volcanics. It is distinguished from these units by the change to massive mudstone from more diverse lithological assemblages. It is conformably overlain by the Flat Top Formation, which is recognised by the change from thick-bedded mudstone to sandstone and conglomerate.

The **undivided Back Creek Group**, where the base is exposed, mostly overlies the Mount Benmore Volcanics in the north and Camboon Volcanics or Woolein beds in the south. Locally, restricted areas of rocks equivalent to the Buffel and Oxtrack Formations have been mapped. On the Rookwood and Duaringa sheets, these rocks are conformably overlain by, and thrust against, the Boomer Formation (discussed below). On the eastern edge of the Gogango Overfolded Zone, the undivided Back Creek Group is overthrust by the Rookwood Volcanics. East of this zone, the contacts are probably mostly faulted (thrust?), although in places the undivided Back Creek Group may overlie the Rookwood Volcanics. The rocks cannot be definitely assigned to one or more of the named formations within the Back Creek Group and contain no diagnostic fossils, although Withnall & others (in preparation) have recognised several unnamed subunits ("Pb_x", "Pb_z",and "Pb_s" with most of the rocks simply being labelled "Pb"). However, the lithological similarities with the Barfield Formation suggests an early Late Permian age, although some equivalents of the late Early Permian Oxtrack Formation and Buffel Formations may be present. The undivided Back Creek Group, along with the Barfield and Oxtrack Formations, was interpreted by Fielding & others (1997) as being deposited during the thermal subsidence phase in the evolution of the Bowen Basin.

Dinner Creek REU — Hunter Bowen Orogen and Foreland Basin

The **Warminster Formation** is located 1km north-west of Mount Chalmers and covers an area of only 300m^2. The unit comprises a fine to coarse sandstone and a massive, poorly sorted, matrix supported, granule to pebble, polymictic breccia. The breccia has a siliceous, fine to coarse sandstone matrix with volcanic, siltstone and cherty-looking clasts. The clasts are up to 30mm in diameter and are angular in shape, which suggests some reworking. Fossils found in the Warminster Formation are marine and indicate a shallow water environment. The age of the unit is Late Permian. A contact has not been observed between the Warminster Formation and underlying Berserker Group. Fossil evidence suggests that an unconformable relationship exists between the Late Permian Warminster Formation and the Early Permian Berserker Group.

The Upper Permian **Moah Creek beds** and **Dinner Creek Conglomerate** unconformably overlie the Lorray Formation and Rookwood Volcanics in the Candlelight Syncline 35km west of Rockhampton. The Moah Creek beds are a nearshore marine unit dominated by a sequence of monotonous mudstone interspersed with beds of comglomerate composed of mudstone rip-up clasts. The Moah Creek beds is a transitional unit from thermal subsidence to foreland basin. Fielding & others (1997) interpreted conglomerates in the Moah Creek beds as debris flows due to submarine mass wasting. They suggested that the rocks were induced by early stages of thrusting in the sub-surface, and reflect the onset of the foreland thrust loading that characterises the later history of the Bowen Basin. The fluviatile Dinner Creek Conglomerate consists mainly of monomict cobble conglomerate and minor interbeds of sandstone and mudstone. The cobbles in the Dinner Creek Conglomerate are almost exclusively fine to medium-grained lithic sandstone, and therefore the conglomerate is markedly different in composition from those in Lower Permian strata (Fielding & others, 1997). Deposition of the Dinner Creek Conglomerate is also interpreted to mark the onset of the final foreland basin phase in the development of the Bowen Basin, related to thrusting during the Hunter Bowen Orogen (Fielding & others, 1997; Fielding & others, 2000).

The **Flat Top** and **Boomer Formations** (and possibly the upper Barfield Formation) units show a change in facies from the mudstone-dominated lower Back Creek Group to sandy facies, which seems to occur at about the same interval as the conglomerates, and may also be related to the foreland basin onset. In the Flat Top Formation sandstones are thin to thick bedded, and have local low-angle cross laminae and grading. They are feldspatholithic, consisting of plagioclase, intermediate volcanic lithics, siltstone and chert. Most of the sandstones are well sorted, but some contain up to 15% matrix. Siliceous siltstone show local graded bedding, soft-sediment deformation and burrows. Calcareous concretions, many of which are fossiliferous, are common near the base of the formation. Fossiliferous conglomerates are locally present. The fossil presence could either indicate shallow water or deeper water in which shallow water-derived sediments were transported by debris flows or turbidity currents. Coal is identified within this formation indicating deposition in a fluviodeltaic environment. The overall depositional model is suggested as an easterly or north-easterly sourced fan delta that rapidly prograded into a shallow sea (Withnall & others, in preparation). The Boomer Formation in the western part of the Rookwood sheet contains abundant lithic sandstone as well as cleaved mudstone. The sandstones are moderately well sorted, lithic sandstones, usually containing >50% fragments of very fine-grained felsic volcanilithics or siliceous siltstone. The sandstones are commonly thick to very thick-bedded and fine to medium grained. Trace fossils are common in the mudstone and tops of sandy beds. Minor plant material is also present as coaly fragments on the tops of some beds. Although most of the rocks are relatively fine-grained, intervals consisting of several thick to very thick beds of very coarse-grained lithic sandstone and granule conglomerate occur. An offshore shelf or ramp environment is interpreted for the unit. Many of the features of the sandstones are suggestive of turbidity flows with intermittent shallower conditions indicated by the hummocky cross-stratification. The provenance mostly seems to be similar to that of the undivided Back Creek Group.

The age of the Boomer Formation is not certain, except that is Late Permian. Possible correlatives of the Boomer Formation may be the Cottenham Sandstone member of the Barfield Formation or possibly the Flat Top Formation that overlies the Barfield Formation. Fielding & others (2000) included the unit within their thermal subsidence package, however, they also state that sandy dominated units of the Back Creek Group preserve evidence of submarine instability and may represent the initiation of the foreland basin phase.

Muncon REU — Continental Volcanics, extensional setting

A period of intrusive and volcanic activity extended from the mid-Permian to the Triassic in the Yarrol Province, with the mid-Triassic to the Tertiary being dominated by crustal extension. Triassic volcanics units, which are relatively undeformed, flat-lying sequences unconformably overlying older rocks, form the Muncon REU. The REU comprises: the rhyolitic to andesitic Winterbourne Volcanics in the Kroombit Tops area, the basaltic to rhyolitic Dooloo Tops Volcanics west of Many Peaks on the Monto sheet, the more basic (andesitic) Muncon Volcanics in the Cania area, the Native Cat Andesite west of Rockhampton, unnamed volcanics at the base of the Upper Triassic Callide Coal Measures and in the Bobby Range east and south of Many Peaks, the dacitic to trachytic volcanics, breccia and small quartz monzodiorite intrusions of the Inverness Volcanics located on the Biloela sheet, and the mainly dacitic to andesitic and possibly basaltic lava flows of the Coulston Volcanics on the Calliope sheet.

The Triassic volcanics of the Yarrol Province are widely distributed with variable rock types suggesting a number of eruption points, at least one of which is a caldera structure covering part of the Kroombit Tops. The Kroombit Tops caldera produced mainly rhyolite, rhyolitic ignimbrite, agglomerate and breccia with only minor amounts of basic lavas towards the base of the sequence. This sequence is referred to as **Winterbourne Volcanics**. An outline of the caldera structure can be defined from airborne magnetics and the location of a cluster of rhyolite domes can be determined from airborne radiometrics. Geological mapping suggests that within the caldera, the eruption sequence moved from west to east with the later rhyolite flows partly obscuring the earlier eruption sequences. Both diagenetic and hydrothermal alteration is widespread with introduced sulphides and carbonates being commonplace. During the Jurassic, this whole volcanic sequence was buried beneath the Precipice Sandstone. Feldspar porphyry dykes intrude both the lower and upper sequences as well as the surrounding rock units. Strontium-rubidium age determinations on whole rock samples taken from both the lower and upper sequences of eruption of the Winterbourne Volcanics have given an age of 218±3Ma.

The **Dooloo Tops Volcanics**, 30km north of Monto, comprise dominantly rhyolitic ignimbrite with a much smaller proportion of intermediate volcanics in the upper part of the pile. The relationship of these volcanics to the nearby western portion of the Glassford Igneous Complex is unclear, however, rhyolitic dyke swarms that form the northern extremity of the volcanics cut the complex, suggesting a younger age.

Unnamed volcanics in the Bobby Range near Barrimoon comprise olivine basalts, pyroxene andesite, and pebbly volcaniclastic sandstone. Three phases are identifiable: a basal unit (Rva) of purple volcaniclastic sandstone, conglomerate, breccia and pyroxene andesite; a middle unit (Ruf) of rhyolitic ignimbrite, breccia flows, dacitic to andesitic volcanic breccia, volcaniclastic sandstone and porphyritic rhyolite dykes; and a top unit (Rub) that hosts the Au and Fe Barrimoon and the Golden Crown mines.

The **Muncon Volcanics** are restricted to an area south and south-west of Cania where they are exposed beneath escarpments of Early Jurassic Precipice Sandstone. The lower part of the unit comprises an interbedded sequence of volcanoclastic pebble conglomerate, tuffaceous sandstone, siltstone and minor basaltic to andesitic lava. Higher in the sequence basaltic to andesitic lavas dominate, and are accompanied by tuffs, volcanic breccia and minor pebble conglomerate. Plant remains identified from near the base of the unit suggest a Early to Middle Triassic age (Dear & others, 1971). The magnetic signature of the Muncon Volcanics is masked, to a large extent, by more strongly magnetised rock types such as diorite and granodiorite that underlie the volcanics and intrude the Youlambie Conglomerate in the Cania area. Where the magnetic signature can be observed, it shows a similar response to that of moderately thick basaltic flows.

The **Native Cat Andesite** is an andesitic volcanic succession extending in an east–west direction ~35km west-south-west of Rockhampton. Airborne radiometrics indicate that there is a difference between the eastern and western portions of the volcanic unit. The eastern portion, approximately as far as Mount Candlelight, exhibits a greater potassium response than the western part that includes Black Mountain. The eastern portion contains a sequence of volcanics that include basic agglomerate and breccia and some breccias that also contain acid volcanic material. The western part of the Native Cat Andesite primarily contains fine-grained andesitic lavas and pyroclastic derivatives.

The **Callide Coal Measures** occur in a north-west trending, roughly rectangular area of land ~10 x 24km, ~15km north-east of Biloela. The Callide Coal Measures are mostly covered by the Precipice Sandstone and rocks of the Biloela Basin and are seen in only a few areas. The unit consists of ~215m of quartzose sandstone, conglomerate, siltstone and coal. The unit has been correlated with the Ipswich Coal Measures by Hill & others (1965) and are interpreted to have deposited in a fluvio-lacustrine environment. Volcanics also occur at the base of the Upper Triassic Callide Coal Measures in the Callide Basin north of Biloela.

The **Coulston Volcanics** form an small ovoid outcrop at Mount Coulston on the Calliope sheet. Elongate east-west the unit covers an area ~3.5km x 2km. This unit consists mainly of grey or pale green, aphyritic to porphyry dacite and andesite. Locally autobrecciated, welded crystal-poor ignimbrite with well-developed eutaxitic layering is present. This unit is associated with a high magnetic response that appears anomalous given the units composition and may reflect an underlying subvolcanic intrusion.

The **Inverness Volcanics** are located in the north-west of the Biloela sheet. The volcanics are dark grey, locally exhibit fragmental textures and contain small plagioclase phenocrysts. Compositionally they are close to rhyodacite. They are intruded by and are probably comagmatic with the Craiglands Quartz Monzodiorite.

Precipice REU — Basin Sag

The **Precipice REU** consists of latest Triassic to Cretaceous sediments, which are considered to represent a succeeding thermal sag phase of basin development. This sequence comprises conformable, relatively undeformed, shallow freshwater fluvial and lacustrine sedimentary units, which reflect a stable, terrestrial environment. This REU includes the following units from oldest to youngest: **Annie Creek beds, Precipice Sandstone, Evergreen Formation, Hutton Sandstone**, and the **Mulgildie Coal Measures**.

The **Annie Creek beds** are a sequence of conglomerate, grey lithic sandstone, grey siltstone and carbonaceous shale that is lithologically distinct from the overlying Precipice Sandstone. They display rapid lateral variation in lithology and thickness, reflecting the irregular nature of the underlying volcanic surface. The conglomerates are composed entirely of fine-grained, grey, cream or green rhyolite, ignimbrite and volcanic breccia in a tuffaceous matrix. Interbedded with these conglomerates are beds of grey, fine-grained sandstone, black carbonaceous shale, siltstone and lithic tuffs. Black carbonaceous shale and thin coal occur locally. The Annie Creek beds are interpreted as having been deposited in a shallow lake environment developed in depressions on the Late Triassic Winterbourne Volcanics.

The **Precipice Sandstone** is found as isolated areas in several parts of the Rockhampton and Monto 1:250 000 sheet areas. The Precipice Sandstone almost always occurs as a ridge-capping, cliff-forming unit. The formation consists primarily of quartzose fine to coarse-grained sandstone, pebbly quartzose sandstone, and some siltstone. Spores have been extracted from the Precipice Sandstone in the Mount Morgan area, and indicate an Early Jurassic age (Playford & Cornelius, 1967). The Precipice Sandstone unconformably overlies many of the Palaeozoic geological units as well as the Triassic Muncon Volcanics. It is overlain conformably by the Evergreen Formation on the Monto 1:250 000 sheet (Dear & others, 1971). On the Rockhampton 1:250 000 sheet, the Precipice Sandstone is overlain by the Stanwell Coal Measures. The boundary is not well exposed, but it is interpreted to be a disconformity (Kirkegaard & others, 1970).

The Early Jurassic **Evergreen Formation** consists of fine-grained flaggy sandstone and siltstone, which conformably overlies the Precipice Sandstone. The sandstones of the Evergreen Formation comprise mainly quartz clasts, but have additional weathered feldspar, light-coloured mica, and some lithic grains. Ferruginous oolitic beds are present and have been suggested (Jensen & others, 1964) to reflect an increase in basin salinity due to a marine incursion, but similar ferruginous oolite in Columbia is considered to have been deposited in fresh water during an interval of minimal deposition of terrigenous sediment (Dear & others, 1971).

The name **Hutton Sandstone** is the name applied to the soft-weathering sandstone that overlies the Evergreen Formation around the Mulgildie Basin. The formation is composed of well-bedded, essentially quartzose sandstone, minor granule conglomerate, and thin sandy siltstone beds. 'Swarms' of clay-siltstone lumps, or clasts, are particularly characteristic of lower sandstone beds. This unusual sandstone probably resulted from wave or current disruption of thin mud beds, and incorporation of the mud clasts in sandbanks. Very shallow water deposition seems likely. No fauna or flora has been obtained from the formation in the Monto 1:250 000 sheet area. In the Surat Basin, the age of the formation is late Early and early Middle Jurassic (de Jersey & Paten, 1964).

The **Mulgildie Coal Measures** comprise siltstone, mudstone, sandstone, and coal beds. They occupy the axial region of the synclinal Mulgildie Basin in the south-eastern part of the Monto 1:250 000 sheet between Monto and Mulgildie. The formation consists of an alternation of sandstone and siltstone, with coal seams occurring at numerous horizons. Little is known of the succession because it is very poorly exposed at the surface. The Coal Measures appear to be brought into juxtaposition with the Evergreen Formation and Hutton Sandstone on their western side by the Anyarro Fault along the line of Three Moon Creek. The Mulgildie Coal Measures were regarded as Middle Jurassic in age by analogy with the Walloon Coal Measures, by Hill & others (1966). The Mulgildie Coal Measures conformably overlie the Hutton Sandstone. The only strata overlying them are unnamed Tertiary freshwater sediments.

Cretaceous — Basins

Crow REU

The Crow REU comprises the **Stanwell Coal Measures** and the **Jim Crow Basin**.

The **Stanwell Coal Measures** are an elongate, east-west running belt of rocks ~16km long, centred roughly on Kalapa. They occur in the very northern part of the Mount Morgan sheet and the southern part of the Ridgelands sheet. The unit produces a subdued landscape, and crops out very poorly. The rocks of this unit consist dominantly of blue siltstone and sandstone with coaly bands up to 10cm thick. The Stanwell Coal Measures were deposited in a small basin, initially marine but changing to a freshwater swampy environment, in which coal beds were formed (Kirkegaard & others, 1970). Spores obtained from core have been identified as of an Early Cretaceous age (Kirkegaard & others, 1970). These sediments, and adjacent older rocks, are overlain by a widespread sequence of continental volcanics of Cretaceous age.

Exploration of a negative gravity anomaly beneath the Mount Jim Crow flats (Esso, 1981) has revealed the Early Cretaceous **Jim Crow Basin**. Drillholes encountered interbedded fine-grained sandstone, siltstone, shale and mudstone in some locations reaching depths of more than 150m without intersecting basement. The gravity data indicate that the basin extends some distance to the north-west beneath Late Cretaceous basalt, but its exact extent is not known. It is uncertain whether the margins of the basin are fault-controlled or merely onlap the older rocks. None of these sediments is exposed at the surface. Fossil pelecypods, dinoflagellates and foraminifera indicate a marine environment and an Early Cretaceous age (Esso, 1981). There is no evidence that conditions changed at any time to a freshwater environment.

Both the Jim Crow and Stanwell basins contain minor coal.

Cretaceous — Continental Volcanics

Westwood REU

Continental within-plate felsic and mafic volcanics were erupted over an extensive area north and west of Rockhampton. This event is represented by the Mount Salmon Volcanics, the Alton Downs Basalt, unnamed basalts (Kb) and the Mount Hedlow Trachyte.

The **Mount Salmon Volcanics** comprise rhyoltic and trachytic flows, breccia, ignimbrite, tuff and minor basalt. They include a number of prominent rhyolite domes, which are believed to be remnants of a large, complex caldera. Basalt lavas, associated with this eruptive phase, extend from Westwood east almost as far as Yeppoon, and have been mapped mainly as the **Alton Downs Basalt**, which has been dated as Late Cretaceous in age. It has been suggested that at least some of the Cretaceous volcanics in the Mount Salmon area were sourced from an extrusion point north of the Native Cat Range (Yarrol Project Team, 1997). Several basalt plugs contain iherzolite xenoliths and xenocrysts of hornblende and pyroxene. Similar material has been mapped at Eulogie Park south of Mount Morgan, and gave a Late Cretaceous age (68.6±0.5Ma, Sutherland & others, 1996). North-west of Wowan, suspected Cretaceous lavas of nephelinitic composition contain both weathered iherzolite xenoliths and hornblende and pyroxene xenocrysts and xenocrysts of garnet and rare anorthoclase. This material is very similar to that in the Brigooda diatreme near Proston from which diamond was recovered (Robertson & Robertson, 1994).

Several trachyte plugs in the Yeppoon area have been collectively termed the **Mount Hedlow Trachyte**. The plugs consist mainly of riebeckite-sanadine trachyte. A Late Cretaceous age of 71Ma has been obtained from a sample from Mount Jim Crow (Willmott & others, 1986). Medium-grained basalts are associated with the trachyte and assumed to be related to the intrusive episode.

Cainozoic Basins

Nagoorin REU

A number of small but deep lacustrine basins in the Yarrol Province are thought to be Cainozoic in age and, their development is believed to coincide with the opening of the Tasman Sea. These basins include the Yaamba (Late Eocene), Casuarina (Eocene), Nagoorin (Tertiary), The Narrows (Middle to Late Eocene), Biloela (Early to mid-Tertiary), Rossmoya (Tertiary), and Aldoga (Tertiary).

Recognised as significant oil shale resources some of these Cainozoic basins (eg The Narrows Graben — Rundle Formation) are also currently being prospected for gas.

Cenozoic — Volcanics and Sediments

Lawgi REU

Basalts crop out particularly in and around the southern end of the Biloela Basin, with the greatest volume being erupted in the mid-Cenozoic. The main period of eruption was from small shield volcanoes around the Oligocene–Miocene boundary (27–22Ma), which produced, with later landscape inversion processes, widespread plateau-areas composed mainly of alkali basalt and hawaiite. These flows are now extensively weathered and in places lateritised (Sutherland & others, 1989). Volcanic activity between 20–18Ma produced a series of plugs and dykes that intruded the older volcanic sequence. This younger sequence comprises olivine melilitite, nephelinite, basanite, hawaiite and alkali basalt, most of which contain upper mantle xenolith and megacryst suites. The emplacement of these younger basalts was controlled by deep-seated fault structures.

Placer Formation REU

The main areas of alluvium are located along Kroombit, Three Moon, Hedlow and Serpentinite Creeks, and the Dee, Calliope, Mackenzie, Boyne and Fitzroy Rivers and their tributaries. Beds of flat-lying Tertiary quartzose sandstones and quartz-pebble conglomerates overlying rocks of the Wandilla Formation occur at scattered localities adjacent to the Narrows channel.

Quaternary coastal sediments include beach ridges and cheniers, high dune systems, estuarine deposits, tidal delta sands, and fluviatile and estuarine clays. The unconsolidated sediments of the Fitzroy delta are up to 50m thick and overlie Tertiary shales and Palaeozoic sediments and acid to intermediate volcanics. They contain salt brine in the layers of sand and gravel (Laycock, 1980).

Marlborough REU

Three large masses of locally deeply weathered ultramafic rocks, with a total area in excess of 900km^2, occur in the Rockhampton-Monto-Marlborough region. The Marlborough mass, which is ~40km long and up to 24km wide, outcrops between Marlborough and the Marble Ridges homestead south of the Fitzroy River. The Mount Etna-Glen Geddes-Kunwarara mass is an elongate belt that runs discontinuously from Mount Etna, through Canoona and Glen Geddes and continues north-west past Kunwarara to a point ~5km south of Mount O'Connell. The total length is 56km, and its width is commonly <2km. From Glen Geddes an offshoot of the main mass extends north for 9.5km and forms the Pointers Range. The Balnagowan-Cawarral- Bondoola mass occurs further east between Balnagowan homestead and Bondoola railway siding, and has a length of ~40km and an average width of <2km. There are also small lenses of ultramafic rock west of Canoona, as well as minor outcrops south of Ubobo, between Many Peaks and the Burnett River.

The ultramafic bodies of the Marlborough REU have an extremely low radiometric response in all channels. This contrasts with a very high magnetic signature. Two bodies with a high magnetic signature similar to that represented by the ultramafics are concealed by Quaternary sediments at the mouth of the Fitzroy River, and at Hedlow Creek near Iron Pot Mountain.

The main rock type in these ultramafic bodies was originally harzburgite, but this has been serpentinised to varying degrees. Small masses of diallage gabbro are included in the ultramafic rocks, and there are dolerite, gabbro, granite pegmatite, and basaltic dykes. The basaltic dykes have altered the serpentinite within several centimetres of their contacts, and in the Glen Geddes-Kunwarara area the basaltic dykes have undergone metasomatic alteration. The age of the harzburgite intrusion is neoproterozoic (Bruce & others, 2000) with emplacement most probably occurring during the latest Permian as a thrust imbricate slice. These rocks are also cut by normal faults of Tertiary age.

A Tertiary weathering profile was developed on the ultramafics and has resulted in chrysoprase and lateritic nickel occurrences. The association of the ultramafic rocks with loosely consolidated Tertiary and Quaternary sediments has also produced diagenetic magnesite.

Intrusive rock units

Middle to Late Devonian Intrusives

The **Mount Morgan Trondhjemite** ranges in composition from quartz gabbro through quartz diorite and tonalite to trondhjemite, but is dominantly a trondhjemite. Typically the trondhjemite consists of approximately equal proportions of plagioclase (sodic andesine) and quartz, which together constitute 90% or more of the rock. Hornblende is the main mafic mineral, with only minor biotite. Geochemically, the trondhjemite has high SiO_2 and extremely low K_2O and is indistinguishable from the volcanics of the Capella Creek Group which it intrudes. A number of geochemical criteria (low Al_2O_3, high heavy rare earth elements, and Rb/Sr ratio) suggest an oceanic island arc setting. Rapid unroofing of the intrusion is indicated by the abundance of trondhjemite clasts in basal conglomerates of the overlying Upper Devonian Mount Hoopbound Formation.

Near the King Solomon and Queen of Sheba mines, ~7km east-south-east of Pomegranate homestead, are scattered small exposures of gabbro. Interpretation of airborne magnetic data indicates that even though the outcrops of the gabbro are small, they are part of a large intrusion at depth. The geophysical signature extends southward to the headwaters of Grasstree Creek, and westward to Pomegranate homestead. The gabbro has strongly hornfelsed the Capella Creek Group, but not the Upper Devonian to Lower Carboniferous Balaclava Formation, indicating that the gabbro was intruded close to the Middle-Late Devonian boundary. A gabbroic intrusion surrounding Prior Park homestead has the same magnetic signature as the gabbro near the King Solomon and Queen of Sheba mines, and has also been interpreted to be of Devonian age.

The **Pomegranate Tonalite** occurs ~2km south of Pomegranate homestead and was originally mapped as part of the Middle Devonian Mount Morgan Tonalite (now Trondhjemite) by Kirkegaard & others (1970). Recent zircon dating returned a Late Devonian date of 369.0±4.2Ma, ~10 million years younger than the Mount Morgan Trondhjemite. However, it is hard to reconcile this age with interpreted stratigraphic and intrusive relationships.

A small, unnamed igneous body at Pomegranate homestead intrudes the Raspberry Creek Formation, but not the Upper Devonian Mount Hoopbound Formation, which is not hornfelsed. The intrusion is therefore regarded as uppermost Middle Devonian or lowermost Late Devonian in age. It ranges from tonalite to granodiorite in composition.

Permian and Triassic Intrusives

High-level I-type granitoids, dominantly of granodioritic and tonalitic composition, were emplaced as widely spaced plutons from the Late Permian to the Late Triassic. Geochemically, these intrusives belong to the Clarence River Supersuite defined in the New England region of New South Wales by Shaw & Flood (1981) and Bryant & others (1997). Subdivisions can be delineated within Permian and Triassic intrusives of the Yarrol Province. Murray (in preparation) describes these using an informal term group because in almost all cases the chemistry of each individual pluton or intrusive phase differs from all others to the extent that definition of suites is not justified. Six groups have been defined, each representing two or more separate plutons or intrusive phases. However, many plutons have unique combinations of geochemical patterns that prevent their inclusion in any of the groups. Distinction between groups is blurred at low levels of SiO_2, and it is also not possible to easily assign to groups the majority of plutons that have only high SiO_2 contents (>70% SiO_2), an exception being the Castletower Granite. This also creates problems for composite plutons with markedly bimodal compositions .

The six groups recognised are:

1. Dumgree group, comprising the Dumgree Tonalite, Bundaleer Tonalite, Norton Tonalite, Umbrella Granodiorite and Rocky Point Granodiorite.

2. Littlemore group, comprising the Littlemore Granodiorite and Lawyer Granite.

3. Craiglands group, comprising the Craiglands Quartz Monzodiorite and Flaggy Quartz Monzodiorite.

4. Monal group, comprising the Monal Granodiorite, Diglum Granodiorite, Bocoolima Granodiorite, and Munholme Quartz Diorite.

5. Ridgelands group, comprising the Ridgelands Granodiorite, Wattlebank Granodiorite, and Lookerbie Igneous Complex.

6. Miriam Vale group, comprising the Miriam Vale Granodiorite (a composite batholith) and the Castletower Granite.

Available geochronological data suggest that there is no simple pattern of geochemical change with time. Also, within batholiths consisting of plutons representing more than one geochemical suite, any one of the suites may be the earliest.

A subduction-related origin has been suggested for intrusives of Early to Middle Triassic age (Gust & others, 1993), and this is supported by the geochemistry and by the spacing of the intrusive centres, which is comparable with the distribution of volcanoes in continental arcs.

Localised Late Triassic continental volcanics may be comagmatic with some of the intrusive rocks.

Most mineralisation in Yarrol is spatially and apparently genetically related to Permian andTriassic plutons.

Craiglands Quartz Monzodiorite

The Craiglands Quartz Monzodiorite is located ~35km north of Biloela. A sedimentary–volcanic sequence forms a thin roof, which covers and is intruded by the main mass of quartz monzodiorite in the west. Aeromagnetic data suggest that it becomes thicker, and the intrusion more deeply buried, towards the east. The north-eastern part of the Craiglands Quartz Monzonite gives a similar radiometric response to the main quartz monzodiorite intrusion, but is much more weakly magnetic, and forms a distinct feature on images generated from the aeromagnetic data. The intrusive rocks in the north-east are similar in composition to samples from the main area of quartz monzodiorite, but are more siliceous. They have significantly lower magnetic susceptibilities. The geochemistry of this intrusive along with the Flaggy Quartz Monzodiorite defines the Craiglands group. This group has lower SiO_2 contents than the Littlemore group, but shares some geochemical features such as high K_2O and Rb, and plots along trend from the Littlemore group for several elements on Harker diagrams. However, compared to the Littlemore group, the Craiglands group has lower MgO and Th. The high level plutonic rocks of the Craiglands Quartz Monzodiorite may be comagmatic with the Inverness Volcanics. SHRIMP zircon dating of the quartz monzodiorite has given an age of 257±3Ma.

There are several small gold deposits around the eastern end of the subsurface intrusion as interpreted from magnetic images (Figure 5 — intrusives and associated mineral occurrences). In addition, some stream sediment samples have given anomalous gold values. In view of this, the fact that the intrusion is high level with coeval volcanics and is a quartz monzodiorite, it is suggested that the area warrants exploration for high-level hydrothermal mineralisation.

Kyle Mohr Igneous Complex

This complex is an ovoid pluton 12km long and 6km wide comprising a central granitic core 8.5km long and up to 4km across surrounded by an almost complete ring of dioritic to gabbroic rocks up to 2km wide. The most common rock type in the outer ring is a grey to dark grey, fine to coarse-grained, mafic-rich gabbro that has been extensively altered and in some cases hornfelsed by the later granitic phase. Typically these rocks consist of subhedral to euhedral plagioclase laths (labradorite) enclosed by ophitic to subophitic augite. Biotite is common, but is largely altered to chlorite. Many of the gabbroic rocks show evidence of hybridisation or hornfelsing by the later granite, including variations in grain size even within a single thin section. Some contain relatively large quartz grains that appear to be associated with the introduction of late stage interstitial sphene.

The most abundant rock type in the central core is a leucocratic biotite-hornblende granodiorite. Plagioclase is always the dominant mineral, comprising from 40–60% of the rock. Mafic minerals rarely constitute >10% of the rock. Green to brown hornblende is much more abundant than biotite, which is largely altered to chlorite. Accessory minerals include opaques, apatite, zircon, and late stage interstitial sphene usually associated with quartz. The almost complete outer ring of dioritic to gabbroic rocks has a very low radiometric response, and a moderate magnetic signature. The central granitic core has a moderate, potassium-rich radiometric signature, and a lower magnetic response. A small area of aplite at the north-west corner of the intrusion has extremely low magnetic susceptibility (9×10^{-5} SI units) and also a low radiometric response.

Concentric granite dykes parallel to the outer contact of the intrusion cut the diorite at the south-eastern end of the complex and is suggestive of a high-level ring complex. In this area, much of the gabbro has been intruded and brecciated by granite. Some gabbro inclusions have crenulate margins, resembling a net-veined complex, indicating that the diorite was still partly fluid when intruded by the granite.

The gabbro phase intrudes the Balaclava Formation to the south of the mass and the Youlambie Conglomerate in the north. The Youlambie Conglomerate has been folded into a tight syncline that parallels the northern margin of the intrusion.

Zircon from granite of the Kyle Mohr Igneous Complex has been dated as mid-Permian (270.6±3.7Ma). The geochemistry of the Kyle Mohr Igneous Complex does not fit within the six groups defined by Murray (in preparation).

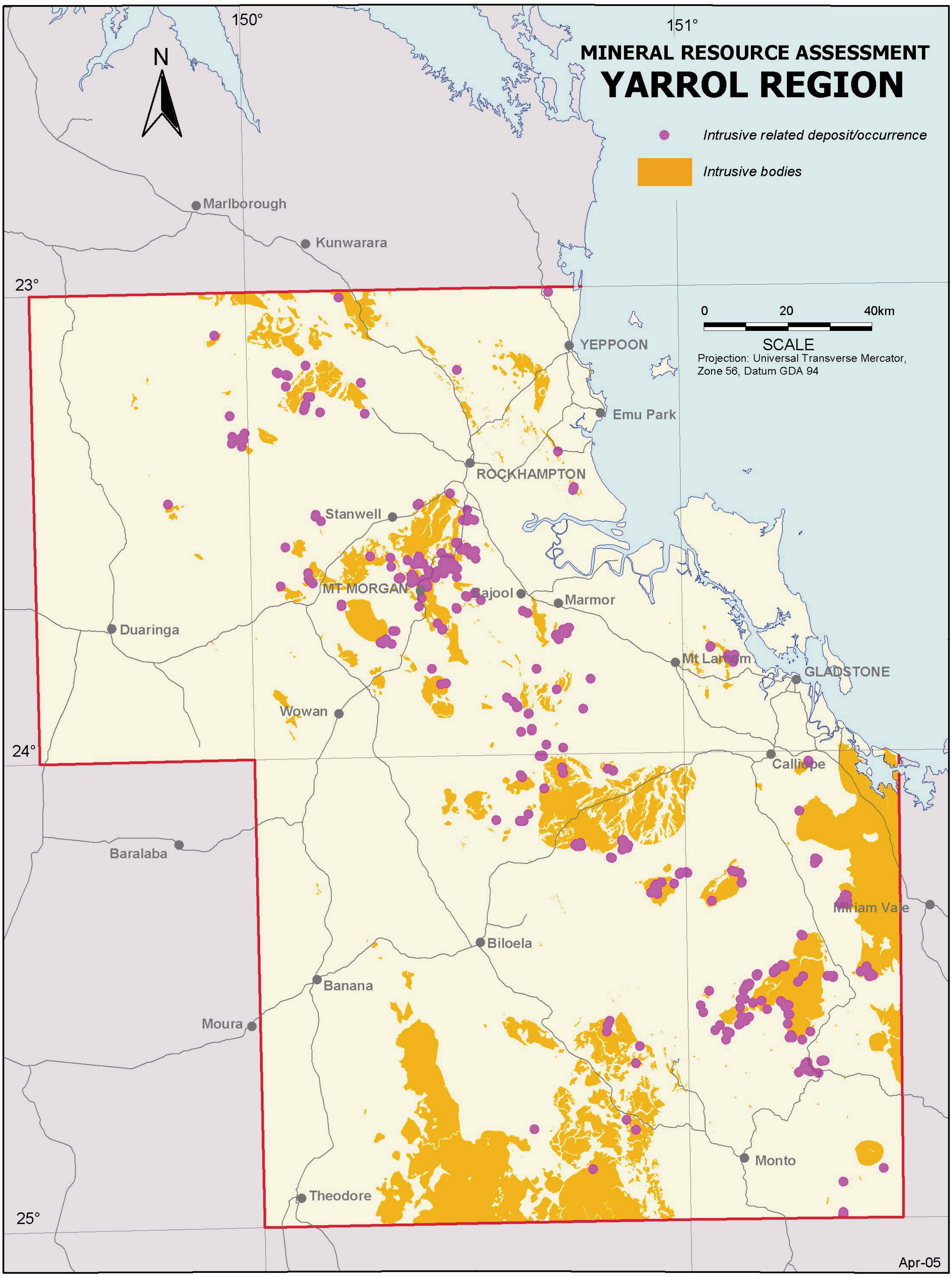
The Dee Copper Mine Group is located in the Balaclava Formation adjacent the southern contact of the Kyle Mohr Igneous Complex.

Wattlebank Granodiorite

Originally this intrusive unit was included as part of the Ridgelands Granodiorite, being both lithologically similar and located just to the north of the Fitzroy River. This fine to medium-grained hornblende-rich granodiorite however, is distinctive from the Ridgelands Granodiorite in terms of its age (dated at 264±5 and 269±5Ma — Middle to Late Permian — Webb, 1969), and a distinctly weaker magnetic response.

The central part of the Wattlebank Granodiorite is a fairly uniform hornblende-biotite granodiorite. Subhedral plagioclase laths make up ~45% of the rock. Quartz forms 25–30% of the rock, occurring as large equant grains to 5mm across. K feldspar constitutes from 10–20%, and forms interstitial to poikilitic grains up to 5mm across. Hornblende and biotite total 10–15% of the rock. Accessory minerals include opaques, sphene, apatite and zircon.

Figure 05 - Intrusives and Associated Mineral Occurrences



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Around the margins of the pluton, including the smaller western outcrop, the composition changes to tonalite.

Airborne magnetic data show that the Wattlebank Granodiorite is a single pluton that is separate from the Ridgelands Granodiorite to the south. Geochemistry of the Wattlebank places it within the Ridgelands group, which comprises the Ridgelands Granodiorite, Wattlebank Granodiorite, and Lookerbie Igneous Complex. This group is intermediate between or overlaps the Dumgree and Monal groups for several elements such as TiO_2, MgO, CaO, total alkalis, Ce and Zr. The main distinguishing feature is its low Sr content, which remains fairly constant at different SiO_2 values.

The Wattlebank Granodiorite intrudes the Princhester Serpentinite, Mount Alma Formation, and unnamed Permian strata, but its relationship to an unnamed gabbro mass south of the Fitzroy River is uncertain. A localised Tertiary deep weathering profile is developed on the larger outcrop. The intrusion of the serpentinites is significant in terms of the timing of the thrust event that emplaced the ultramafics.

A sample of tonalite from the southern bank of the Fitzroy River at Eden Bann homestead gave K-Ar dates on hornblende of 264 and 269±5Ma (Webb, 1969). This Middle to Late Permian age is considerably older than that obtained for the Ridgelands Granodiorite.

No mineralisation is known to be associated with the Wattlebank Granodiorite.

Bouldercombe Igneous Complex

The Bouldercombe Igneous Complex is dumbbell-shaped consisting of elliptical eastern and western lobes, which are similar in area and jointly extend across 40km. Three separate gabbro bodies, the Gracemere Gabbro, Gavial Gabbro, and Quarry Gabbro, form a discontinuous arcuate belt around the periphery of the eastern lobe, most of which consists of a leucocratic tonalite, the Bundaleer Tonalite. The youngest intrusions are the Kabra Quartz Monzodiorite, which cuts both the Bundaleer Tonalite and the Gracemere Gabbro, and the small Moonmera Porphyritic Granodiorite, in which the Moonmera porphyry copper deposit is hosted. The oldest marginal phase of the intrusion of the western lobe is the Flaggy Quartz Monzodiorite. This intrusion is ~2km wide and is strongly foliated. The central part of the western lobe is occupied by massive granodiorite and granite of the Umbrella Granodiorite and the Moonkan Granite, and contains small areas of altered rocks including quartz porphyry, breccia, and greisen. Ages ranging from Late Permian to Middle Triassic (264–234Ma) have been obtained from several phases of the Bouldercombe Igneous Complex.

Geochemistry suggests a subduction-related origin.

The **Gracemere Gabbro** forms the north-east extremity of the Bouldercombe Igneous Complex. The intrusive is a uniform, grey, medium to coarse-grained gabbro with a prominent foliation due to alignment of plagioclase laths.

A sample of the Gracemere Gabbro from the type area was dated by Webb & McDougall (1968). They obtained a result of 244±5Ma (Early Triassic) by K-Ar dating of biotite, corrected to new constants. However, the Bundaleer Tonalite, which is interpreted to intrude the Gracemere Gabbro, has given Late Permian ages. Therefore, a Late Permian to Early Triassic age is assigned to the Gracemere Gabbro. The airborne magnetic data clearly show that the Gracemere Gabbro is truncated to the west by the Kabra Quartz Monzodiorite.

The Hector mine, reputed to be the first lode gold mine worked in Queensland, is located at the southern margin of the Gracemere Gabbro. It is not known whether the mineralisation is associated with the gabbro itself, or with felsic dykes, which are presumably related to the adjacent Bundaleer Tonalite. Smaller gold mines also occur within the sedimentary country rocks in this vicinity.

The **Bundaleer Tonalite** is the most extensive unit within the Bouldercombe Igneous Complex, forming a north-east trending belt ~16km long and 8km wide from the Razorback Range almost to Gracemere. The tonalite is a pale grey medium-grained leucocratic hornblende-biotite tonalite. The Dumgree Tonalite together with the Bundaleer Tonalite, Norton Tonalite, Umbrella Granodiorite and Rocky Point Granodiorite comprise the Dumgree group. On Harker diagrams, this group is characterised by high Al_2O_3, CaO, and Sr, and low TiO_2, MgO, and total alkalis. K_2O, Ce, Rb, Th, Y and Zr are all low and, for the group as a whole, tend to decrease with increasing SiO_2.

Webb & McDougall (1968) dated a single sample of the Bundaleer Tonalite from a cutting along the abandoned Mount Morgan-Kabra railway line, and obtained a K-Ar biotite age of 242±5Ma (recalculated). Subsequent dating of samples from the same locality, reported by Green (1975) and Ford & others (1976), gave results of 251±5 and 264±5Ma from K-Ar dating of biotite, revised to new constants, and 250±8Ma from hornblende. On the basis of these results, the Bundaleer Tonalite is assigned a Late Permian to Early Triassic age. The tonalite appears to intrude the Gracemere Gabbro, is intruded by the Moonmera Porphyritic Granodiorite, and is interpreted as being intruded by the Kabra Quartz Monzodiorite and by undivided rocks of the complex south of Table Mountain. Relative age relations with the Gavial Gabbro and Quarry Gabbro are unknown.

The Bundaleer Tonalite is not known to be associated with any significant mineralisation.

The **Gavial Gabbro** is a grey to dark grey medium-grained gabbro with local compositional banding. It intrudes the Devonian Capella Creek Group and Devonian to Carboniferous Mount Alma Formation. Its relationship with the Bundaleer Tonalite cannot be determined due to lack of outcrop. The marginal position of the gabbro suggests that emplacement preceded that of the tonalite, but its irregular shape is more consistent with intrusion after the tonalite. The Gavial Gabbro is assigned a Late Permian to Early Triassic age.

Several gold workings in the Bouldercombe area, the largest of which is the Mount Usher mine, are hosted by the Gavial Gabbro. There appears to be a genetic relationship between intrusion and mineralisation.

The **Quarry Gabbro** is a relatively small east-west trending intrusion ~4.5km long, centred ~2.5km south-east of the Stanwell power station. It is a dark grey to black medium-grained gabbro. The Quarry Gabbro is assigned a Late Permian to Early Triassic age. Its relative age relationships with the Bundaleer Tonalite are unknown.

The Quarry Gabbro is not known to be associated with any significant mineralisation. Large boulders from a site 3km south-east of the Stanwell power station have been quarried as a source of black granite for the building stone industry.

The **Kabra Quartz Monzodiorite** is shown in airborne magnetic data as a distinct phase in the eastern lobe of the Bouldercombe Igneous Complex. The intrusion is centred ~15km south-west of Rockhampton where it forms an elongate mass 10km long and 4km wide extending from the cattle saleyards at Gracemere in the north to Table Mountain in the south. . The deeply weathered northern end of the intrusion forms low country traversed by the Capricorn Highway. In contrast, the southern portion is hilly and includes the steep-sided Table Mountain.

Predominantly an altered grey hornblende-quartz monzodiorite it has lesser amounts of hornblende-augite-quartz gabbro. The radiometric response of the body is varied, and can be correlated with the topography. The northern weathered section gives a low response, whereas the southern hilly part gives a moderate response dominated by potassium. The magnetic pattern of the Kabra Quartz Monzodiorite on images derived from aerial data shows most of the intrusion as having a moderate to high magnetic signature, consistent with magnetic susceptibility readings averaging 2840 x 10^{-5} SI units. However, a band of very low magnetism is evident down the centre of the body. Readings taken within this zone have higher than average susceptibility due to reverse remnant magnetism, suggesting either that the intrusion is composite, or that a reversal occurred during crystallisation

Geochemical analysis of samples of the Kabra Quartz Monzodiorite indicates it is most like the Graiglands group, but there are differences that exclude it from all groups. A Triassic age has been assigned to the Kabra Quartz Monzodiorite because it appears to cut both the Gracemere Gabbro and the Bundaleer Tonalite.

Two magnetite skarns are located on the northern contact of the Kabra Quartz Monzodiorite and the Rockhampton Group.

The **Moonmera Porphyritic Granodiorite** is a small composite intrusion covering <1km^2 on the slopes of the Razorback Range, 7km north of Mount Morgan. The intrusion corresponds with an area of low magnetic and high radiometric response relative to the surrounding Bundaleer Tonalite, caused by demagnetisation and potassic alteration respectively. The Moonmera Porphyritic Granodiorite has been described by Ayres (1974), Whitcher (1975), Dummett (1978) and Male (1992). The following summary is compiled from their work.

The intrusion consists of at least two phases of altered porphyritic biotite granodiorite and a hypabyssal breccia pipe. Numerous dykes, some radial and some forming incomplete ring structures, surround the intrusive complex. Emplacement of the younger porphyry was associated with brecciation of the surrounding rocks. The breccia pipe, termed tuffisite by Dummett (1978), includes clasts of both older and younger porphyritic granodiorite phases, of the Bundaleer Tonalite, and of some rock types which are not exposed in the area. Extensive and locally intensive alteration of the porphyritic granodiorite bodies presents a problem for interpretation of their primary geochemistry and this intrusive has not been assigned to any geochemical group. However, the range of SiO_2 values for each of the two main phases of porphyritic granodiorite are quite restricted, suggesting that Si was relatively constant during alteration, and that these phases represent distinctly different primary compositions. Dykes show a much wider range of SiO_2 contents. Some correspond to the two main porphyritic granodiorite phases, whereas others are not related.

The Moonmera Porphyritic Granodiorite hosts copper mineralisation at the Moonmera Group mines.

The **Flaggy Quartz Monzodiorite** forms an arcuate band 12km long and ~2km wide around the southern margin of the western lobe of the Bouldercombe Igneous Complex. Airborne magnetic data suggest that it continues as a marginal phase around the concealed northern part of this lobe. The Flaggy Quartz Monzodiorite displays a prominent foliation in all outcrops. The foliation is generally vertical and parallel to the southern curvilinear intrusive boundary and is considered to be related to the emplacement of the quartz monzodiorite.

The Flaggy Quartz Monzodiorite has been assigned to the Craiglands group. This group has lower SiO_2 contents than the Littlemore group, but shares some geochemical features such as high K_2O and Rb, and plots along trend from the Littlemore group for several elements on Harker diagrams. However, compared to the Littlemore group, the Craiglands group has lower MgO and Th. Geochemically, the Flaggy Quartz Monzodiorite is quite distinct from the Umbrella Granodiorite and the Moonkan Granite, the other phases of the western lobe of the Bouldercombe Igneous Complex. Each of the granitoids falls within a relatively small range of SiO_2 contents, and there is no overlap between them. The geochemical data suggest that the Flaggy Quartz Monzodiorite has no simple genetic relationship with either the Umbrella Granodiorite or the Moonkan Granite. The Flaggy Quartz Monzodiorite has been dated with a Late Permian age. It is not known to be associated with any mineralisation. Local pegmatitic patches contain relatively coarse magnetite crystals.

The **Umbrella Granodiorite** is the most extensive phase of the western lobe of the Bouldercombe Igneous Complex, covering an area ~12km long and 4km wide in the central part of the lobe. Outcrop is uniform in composition - a pale grey, medium-grained, massive biotite-hornblende granodiorite. This granodiorite falls within a fairly narrow range of SiO_2 from 60–65%. For most discriminating elements, including Na_2O+K_2O, K_2O, CaO, Ba, Rb, Th and Y, the intrusion plots as a member of the Dumgree group, with low TiO_2, MgO and Zr. The age of the Umbrella Granodiorite is unclear. K-Ar dating of biotite gave an age of 243±5Ma, or Early Triassic (Wood, 1974; Ford & others, 1976). However, the Moonkan Granite, which intrudes the Umbrella Granodiorite, has given dates as old as latest Permian. Therefore, a Late Permian to Early Triassic age has been assigned to the Umbrella Granodiorite.

This intrusive phase is associated with localised alteration systems, brecciation and intrusion of small quartz porphyry plugs in the Sandy Creek area, which are considered to be a late stage of the magmatic event, which produced the Umbrella Granodiorite and Moonkan Granite.

The **Moonkan Granite** is a pale pinkish grey, massive, equigranular, medium-grained hornblende-biotite granite, locally containing sparse fine-grained grey xenoliths. The main pluton is located in an area east of Mount Hay with other smaller outcrops about Sandy Creek and south of Mount Gordon.

The Moonkan Granite intrudes the Umbrella Granodiorite. At its western extremity, the Moonkan Granite is intruded by the Cretaceous rhyolite plug, which forms Mount Hay. Webb & McDougall (1968) dated biotite from a sample collected along Sandy Creek as 243±2Ma (corrected to new constants), which is the same as the date from the Umbrella Granodiorite. However, K-Ar ages of 251±5 and 257±5Ma were obtained on biotite from a sample from the main outcrop area (Wood, 1974; Ford & others, 1976). Therefore, the Moonkan Granite has been assigned a Late Permian to Early Triassic age.

Small outcrops of the Moonkan Granite in the Sandy Creek area are spatially related to hydrothermal alteration and breccia pipe development associated with minor gold mineralisation (Wood, 1974).

Unnamed intrusions (Prgbe) are concentrated in an east-north-east trending belt ~5km long extending from Sandy Creek to Mount Gordon. These youngest of intrusions in the western lobe of the Bouldercombe Igneous Complex are small stocks, plugs and dykes of quartz porphyry and diorite, which are associated with breccia development and alteration, including greisenisation. Because of their small size and close spatial relationship, they have been grouped together. Quartz porphyry forms Mount Gordon and Mount Coombs, and another small plug on the west bank of Sandy Creek is centred at GR 219000.7389825 (GDA). A small mass of altered rock, similar in composition to the quartz porphyry, occurs on the eastern side of Pilkington Creek, centred at GR 223150.7391375. The largest outcrop of diorite is just east of Sandy Creek at GR 219625.7389000.

Coarse sericite from an altered collapse breccia pipe just east of Sandy Creek gave an Ar/Ar date of 251±5Ma (recalculated) (Wood, 1974; Ford & others, 1976). The close spatial relationship between the hydrothermal alteration and the quartz porphyry intrusives suggests that the alteration and formation of the collapse breccia is close to the age of intrusion. If so, emplacement of the Umbrella Granodiorite and Moonkan Granite, intrusion of the quartz porphyries, hydrothermal alteration and brecciation may all represent different phases of the same Late Permian to Early Triassic magmatic event. Samples of hornblende diorite taken from Mount Gordon were dated at 234±10Ma and 237±10Ma (recalculated) (Wood, 1974; Ford & others, 1976) and support the view that the diorite intrusions post-date the alteration.

The close spatial relationship of the quartz porphyry intrusions to hydrothermal alteration and breccia pipe development associated with minor gold mineralisation suggests a direct genetic connection. Wood (1974) considered that the diorites post-dated the mineralising event.

Kariboe, Eulogie and Bucknulla Gabbros

A chain of gabbroic intrusions forming a roughly linear north-west trending belt extends from north-east of Brisbane to south-west of Rockhampton. From south to north these intrusions are the Somerset Dam Igneous Complex, Wateranga Gabbro, Hawkwood Gabbro, Goondicum Gabbro, Kariboe Gabbro, Eulogie Park Gabbro and Westwood/Bucknalla Gabbro. Several of these intrusions are located in the assessment area and have been explored for platinum group metals and/or magnetite with varying success.

The **Kariboe Gabbro** covers >20km^2, outcropping in the Spring Creek region, south-east of Biloela. This intrusive, which includes a layered gabbro sequence, is dominated by hornblende gabbro, but also includes hornblende diorite, tonalite, quartz monzogabbro-diorite and rare hornblendite. Locally the rocks contain xenoliths of metasiltstone-schist. The layered gabbro sequence has been subdivided into four zones comprising the dominant rock types: ferrigabbro, olivine gabbro, hypersthene gabbro, and phenocrystic augite gabbro.

A diorite body crops out on the southern and western margins of the layered gabbro and is considered to have intruded the gabbro when the latter was still hot, indicating that they are of virtually the same age. The presence of similar dated intrusive diorite in the Eulogie Park Gabbro (see below) and the absence of other definitive intrusive relationships, suggests a tentative Permian-Triassic age for the Kariboe Gabbro.

Copper mineralisation has been known in the Spring Creek area since the mid-1800s, with two major deposits worked at Great Blackall and Flanagans. The larger deposit, the Great Blackall Mine, is located in the diorite. Flanagans Workings, the other significant group of mines in the Spring Creek area, in hosted in gabbro and is located on a ridge

~1km north-east of the Great Blackall Mine. Pechiney (Australia) Exploration Pty Ltd drilled three cored holes in the Kariboe Gabbro in the early 1970s. Analysis of this core in 1983 by Mareeba Mining and Exploration Pty Ltd provided highest assay results of 155ppb gold and 6ppm silver.

The **Eulogie Park Gabbro** is located ~25km south of Mount Morgan. Originally a saucer-shaped lopolith, it has been disrupted by faulting and the intrusion of a larger mass of diorite. The main section has at least 65 persistent layers consisting of olivine gabbro, troctolite, ferrogabbro, leucogabbro and titaniferrous magnetite bands (Wilson & Mathison, 1968). The magnetic signature of the body shows the innermost core reversally magnetised and the outer rim with normal magmatism. The Eulogie Park Gabbro has been given an Early Triassic age (241.6±3Ma) based on dating of the diorite. The gabbro intrudes the Balaclava Formation.

The intrusion has been evaluated for magnetite resources and also prospected unsuccessfully for platinoids.

The **Bucknalla Gabbro** is a triangular-shaped intrusion located just west of Westwood. Compositionally it consists in the south-west of feldspathic clinopyroxenite which is apparently overlain by a layered unit of olivine gabbro, leucogabbro, troctolite, ferrigabbro and anorthosite. Two types of layering are evident: igneous lamination (alignment of tabular plagioclase laths) and rhythmic layering (changes in the proportion of minerals). The layers are discontinuous in the Bucknalla, unlike Eulogie Park where 1m thick layers persist over distances of 5km. A feature of this mafic mass is its extremely calcic plagioclase composition.

The Bucknalla intrudes the Rookwood Volcanics and the Flaggy Creek Quartz Monzodiorite.

It has been dated at 200.8±6Ma (Holcombe & others, 1997a). The Bucknall Complex contains disseminated copper and platinum group mineralisation (Reeves & Keays, 1995)

Lookerbie Igneous Complex

The Lookerbie Igneous Complex is centred 25km south of Biloela. It occurs to the north-east of Mount Lookerbie as a north-west trending belt ~6km wide by 15km long. Rock types include diorite, gabbro, tonalite, granodiorite, quartz diorite and andesite. The plutonic rocks are commonly quite strongly altered, with sericitisation of the plagioclase and chloritisation of the mafic minerals.

The geochemistry of the Lookerbie Igneous Complex places it within the Ridgelands group, along with the Ridgelands Granodiorite and the Wattlebank Granodiorite. The main distinguishing feature of this group is its low Sr content. Rocks of the adjacent Camboon Volcanics are hornfelsed near the margins of the Lookerbie Igneous Complex suggesting a probable Permian-Triassic age for this unit.

Galloway Plains Igneous Complex

Galloway Plains Igneous Complex comprises a number of plutons ranging in composition from gabbro to granite. One unnamed and seven named units are defined: unnamed gabbro (Prgau), Sawnee Gabbro, Dumgree Tonalite, Rocky Point Granodiorite, Wyalla Granite, Redshirt Granite, Bocoolima Granodiorite, Voewood Granite. In common with other composite intrusions in the assessment area, mafic rocks are restricted to the outer margins of the batholith, whereas granites occur in the centre.

Aeromagnetic data show that the Galloway Plains Igneous Complex consists of two magnetically contrasting parts with the western more strongly magnetic than the eastern. There is reasonable outcrop over much of the western part which is divided into the Dumgree Tonalite in the north and the Rocky Point Granodiorite in the south. Chemical analyses also form two significantly different trends. This subdivision reflects broad compositional trends, however, in detail within these two units there are variations for example, there are areas of quartz diorite to tonalite within the Rocky Point Granodiorite.

Locally the Dumgree Tonalite is cut by north-east trending rhyolite dyke swarms genetically related to the intrusion of the Redshirt Granite. Strongly magnetic diorite and gabbro locally occur around the periphery of the Dumgree Tonalite and may represent its marginal phases. The prominent magnetic feature associated with the northern most diorite–gabbro phase (the Sawnee Gabbro) continues to the south-east into a linear magnetic high, which is correlated with a zone of metamorphosed contact rocks including limestone. Both the Rocky Point Granodiorite and Dumgree Tonalite are intruded by the Wyalla Granite. The eastern part of the Galloway Plains Igneous Complex, named the Bocoolima Granodiorite, appears to consist of a series of nested plutons indicated by arcuate to elliptical magnetic rims. The Bocoolima Granodiorite is cut by prominent north-west to north-north-west trending dykes of generally andesitic composition, and is also intruded by the Voewood Granite, which has closely spaced joints filled with pyrite-bearing quartz veins.

The **Bocoolima Granodiorite** is a large deeply weathered pluton located ~30km west-south-west of Calliope. Outcrop on the western margin is a grey medium-grained biotite-hornblende granodiorite. The pluton has a low magnetic signature with the exception of some prominent north-west to north-north-west trending andesite dykes. Aeromagnetic data suggests that the Bocoolima Granodiorite may be a set of nested plutons rather than a single body.

The geochemistry of the Boocoolima Granodiorite places it within the Monal group, which includes the Monal Granodiorite, Diglum Granodiorite, and Munholme Quartz Diorite. This group is intermediate between the Dumgree and Littlemore groups on Harker plots for several elements, but overlaps these two groups, and reaches extreme values in some cases. The Littlemore group shows curved (fractionated) trends for Ce, Y and Zr. The trend for Sr is similar to that of the Littlemore group, with relatively high values that decrease with increasing SiO_2.

No age dating has been done on the Bocoolima Granodiorite. Relationships to the Dumgree Tonalite and Rocky Point Granodiorite are uncertain. Whilst the Bocoolima pluton appears to intrude them, the magnetic signature is ambiguous. The Bocoolima is intruded by the Voewood Granite, which has been dated at 233±7Ma, as such it has been assigned a Permo-Triassic age. The shape of the contact suggests that it is intruded by the Rocky Point Granodiorite, although complex magnetic patterns across the boundary are difficult to interpret. The Bocoolima Granodiorite intrudes the Three Moon Conglomerate, Mount Mount Alma Formation, Rockhampton Group and the Youlambie Conglomerate.

The Maxwelton Goldfield is hosted in contact rocks of the Three Moon Conglomerate near the junction between the Rocky Point Granodiorite and the Bocoolima Granodiorite.

An **unnamed gabbro (PRgau)**, consisting of a medium-grained quartz-augite-hypersthene-hornblende rock, forms near the headwaters of Back Creek. This unit intrudes the Youlambie Conglomerate. No contacts have been identified with the Dumgree Tonalite and the relative age of the two units is unknown. No samples have been dated, however, a Permian to Triassic age has been assigned based on results from other units in the complex.

The **Sawnee Gabbro** forms a continuous east-west belt ~8km long and up to 1km wide between the headwaters of the Don and Calliope Rivers along the north-western extremity of the Galloway Plains Igneous Complex. Small separate mafic intrusions immediately to the north may be related to the Sawnee Gabbro. The most common rock type of this unit is a hornblende gabbro, with lesser amounts of hornblende-hypersthene-augite gabbro.

The Sawnee Gabbro is assumed to represent one of the earliest phases of the Galloway Plains Igneous Complex, and is assigned a Late Permian to Early Triassic age. The gabbro intrudes the Balaclava Formation to the north and the Youlambie Conglomerate to the west. The spatial relationships of the Sawnee Gabbro to the Dumgree Tonalite suggest that it is intruded by the tonalite.

The Sawnee Gabbro has been investigated as a source of magnetite, but no concentrations of economic significance were found. It is associated with small garnetiferous skarn deposits in the Balaclava Formation, some of which contain minor base metals.

Rocky Point Granodiorite is a biotite-hornblende granodiorite, with the main variation being an area of pyroxene-biotite-hornblende quartz diorite ~2km by 1km that extends south-south-west from Rocky Point Mountain. The quartz diorite and minor quartz gabbro near Rocky Point Mountain are fairly uniform in composition, consisting of 65–75% plagioclase and ~10% quartz. The main mafic minerals are green-brown hornblende (10–15% of the rocks) and biotite (5–15%).

Analysed samples of the Rocky Point Granodiorite place it geochemically within the Dumgree group. The Rocky Point Granodiorite intrudes the Youlambie Conglomerate, Balaclava Formation, Raspberry Creek Formation, Mount Alma Formation, Rockhampton Group and Three Moon Conglomerate, and is overlain by Tertiary basalt. The relative ages of the Dumgree Tonalite, Rocky Point Granodiorite and Bocoolima Granodiorite are unknown. The contact with the Bocoolima Granodiorite is interpreted to lie along an arcuate magnetic feature concave to the east, suggesting that the Rocky Point Granodiorite is older. A small lens of garnet-clinopyroxene-plagioclase hornfels occurs along the contact and is interpreted as a screen of country rock partially separating the two intrusions. Relationships between phases in the Rocky Point Granodiorite are clearly displayed in outcrop where hypersthene-augite-biotite-hornblende quartz gabbro is intruded by and occurs as blocks in foliated grey biotite-hornblende quartz diorite. Dykes and small masses of pink to grey locally leucocratic biotite granodiorite cut both gabbro and diorite.

Webb & McDougall (1968) dated two samples from the Rocky Point Granodiorite. Sample GA1167 located on the Dawson Highway near the interpreted boundary between the Dumgree Tonalite and Rocky Point Granodiorite gave K-Ar dates of 244±5Ma (biotite) and 240±5Ma (hornblende), and sample GA1166 from the headwaters of Collards Creek gave 244±5Ma (biotite) and 247±5Ma (hornblende), suggesting an Early Triassic age. However, emplacement of the Dumgree Tonalite and Rocky Point Granodiorite is considered to have been essentially synchronous, as they appear to be part of a single large pluton.

The Mount Rainbow Goldfield lies within the southern part of the Rocky Point Granodiorite. Most of the production came from deep leads in sediments at the base of Tertiary basalt flows, but the gold was sourced from quartz veins in the granodiorite itself or in the adjacent country rocks. The Maxwelton Goldfield worked auriferous quartz veins in the Three Moon Conglomerate near its contact with the Rocky Point Granodiorite and Bocoolima Granodiorite.

The Dumgree Tonalite appears as a fairly uniform body ranging from quartz diorite to granodiorite in composition. Tonalite is dominant, but some samples are so low in mafics that they can be classed as trondhjemites. The more mafic varieties come from the western edge of the pluton, particularly around the unnamed gabbro intrusion. Rock samples have an even medium-grain size, and are grey to white depending on the proportion of mafic minerals present. Green-brown hornblende is the most abundant mafic mineral.

The **Dumgree Tonalite** is one of the defining units of the Dumgree group, characterised by low total alkalis, TiO_2, MgO and high Al_2O_3, CaO and Sr. K_2O, Ce, Rb, Th, Y and Zr are all low and for the group as a whole tend to decrease with increasing SiO_2. The Dumgree Tonalite has well defined linear trends on Harker diagrams that in some cases differ from those of the overall group, notably Rb, Th and Zr that all increase slightly with increasing SiO_2. It is distinguished geochemically from the Rocky Point Granodiorite by lower TiO_2, MgO, K_2O, Ce, Rb, Th, V, Y and Zr and higher Al_2O_3, Na_2O and Sr.

Emplacement of the Dumgree Tonalite and Rocky Point Granodiorite is considered to have been essentially synchronous, as they appear to be part of a single large pluton. Webb & McDougall (1968) dated two samples from these intrusions and obtained Early Triassic K-Ar ages for both. However, the Redshirt Granite, which intrudes the Dumgree Tonalite, gave a U-Pb zircon date of 251±4Ma, and therefore all three units have been assigned a Late Permian to Early Triassic age.

The Dumgree Tonalite intrudes the Youlambie Conglomerate, and is intruded by the Redshirt Granite and part of its associated dyke swarm. It is assumed to intrude the Rocky Point Granodiorite because of their spatial relationship, and may also intrude the unnamed gabbro at the western extremity of the Galloway Plains Igneous Complex.

The only significant mineralisation known from the Dumgree Tonalite is in the Fig Tree Provisional Goldfield north of Mount Redshirt. The gold mineralisation was probably related to the prominent north-east trending dyke swarm associated with the Redshirt Granite, rather than to the Dumgree Tonalite itself.

The **Wyalla Granite** is a small pluton that intrudes across the interpreted contact of the Rocky Point Granodiorite and the Dumgree Tonalite. A pink medium-grained biotite granite, it has a moderate radiometric and low magnetic response. A more magnetic rim is evident in surrounding host rocks. A

Permo-Triassic age has been assigned to this intrusion.

There is no mineralisation known to be associated with the Wyalla Granite.

The **Redshirt Granite** forms the prominent peak of Mount Redshirt, 40km north-north-east of Biloela. Handspecimens reveal a pink, coarse-grained hornbende-biotite granite with minor tourmaline pegmatite. Plagioclase is the most abundant mineral, comprising from 35–40% of the rock. K-feldspar (25–35%) locally forms micrographic intergrowths with quartz, the later making up 20–30% of samples taken. Biotite is the main mafic mineral, comprising up to 10% of the rock. Accessory minerals include sphene, opaques, apatite, zircon, and zoned tourmaline. An extremely high radiometric signal is recorded over this intrusive phase.

A U-Pb age determination on zircon from the Redshirt Granite gave an age of 251±4Ma, straddling the Permian-Triassic boundary. This age is slightly greater than, but within the experimental error of K-Ar dates from the Rocky Point Granodiorite and Dumgree Tonalite. A Late Permian to Early Triassic age has been assigned to all three units.

The Redshirt Granite intrudes the Dumgree Tonalite and appears to be the source of the north-east trending rhyolite dyke swarm that cuts the Dumgree Tonalite. The dyke swarm is associated with gold mineralisation.

The **Voewood Granite** forms as a 7.5km long and 2km wide body that intrudes the Bocoolima Granodiorite. A pale pink to grey medium-grained hornblende biotite granite, plagioclase is always the most abundant mineral (35–50% of rock). Microcline (20–30%) forms interstitial to poikilitic grains up to 3mm across, and is accompanied by anhedral quartz crystals up to 4mm across (25–30% of rock). Biotite comprises ~5% of the rock, with minor and accessory opaque grains, sphene, apatite and zircon. Muscovite occurs as relatively large flakes in some specimens, and may be primary. The western part of the intrusion is strongly jointed with pyrite-bearing quartz veins along the joints. The intrusive has a moderate radiometric and overall low magnetic response, although a more magnetic rim is evident.

The Voewood Granite has given a U-Pb zircon age of 233.6±6.8Ma (Middle to Late Triassic). Apart from the pyrite-bearing quartz veins, no mineralisation is known to be associated with the Voewood Granite.

Mount Seaview Igneous Complex

A triangular shaped pluton, with a maximum east-west width of 7.5km and a north-south length of 7km, the Mount Seaview Complex consists of a granitic core completely surrounded by diorite. The high peak of Mount Seaview, Fatters Hat, is a pink medium-grained altered, leucocratic biotite granodiorite to granite. Plagioclase comprises about half the rock. Quartz ranges from 20–30%. The proportion of K-feldspar is difficult to estimate, but averages ~15%. Biotite never makes up >10% of the rock. Accessories include opaques, apatite, sphene and zircon. Pyrite occurs locally along joint planes. A zone of coarse breccia is developed on Griffiths Hill. The granitic phase returns low magnetic and high radiometric responses.

Outcropping on the plateau about Mount Seaview, the mafic rim consists mainly of grey, medium to coarse-grained, augite-biotite-hornblende quartz diorite. Subhedral plagioclase laths make up ~65% of the rock. Anhedral, interstitial quartz grains comprise up to 10% of the rock, and rare interstitial to poikilitic K-feldspar is present. The proportion of mafic minerals is fairly uniform at ~25%. Green hornblende is generally most abundant, replacing and rimming augite, however, biotite is as abundant as or even exceeds hornblende in some samples. Minor hypersthene is present. Accessory minerals include zircon, opaques, apatite, and sphene. One sample from the eastern edge of the intrusion is a dark grey, medium-grained, hornblende-augite-biotite-hypersthene quartz gabbro in which hypersthene is the main mafic mineral. The plateau area has a low radiometric response and a high magnetic response that extends further south than the exposed boundary. A much stronger magnetic response of the southern section of the dioritic rim, part of which is concealed by volcaniclastic contact rocks, may also reflect compositional variations.

The felsic core of Mount Seaview appears to be completely encircled by the mafic rim suggesting that the quartz diorite was emplaced first, and was intruded by the granodiorite to granite phase. The quartz diorite intrudes the Three Moon Conglomerate, Rockhampton Group, and Youlambie

Conglomerate. A small outlier of Jurassic Precipice Sandstone overlies the felsic phase on Griffiths Hill (Denmead, 1932), indicating that the intrusion had been unroofed by the end of the Triassic. U-Pb dating of zircon from a sample of the felsic phase gave a bimodal age distribution. The older population gives a result of 258±4.3Ma, and the younger population 238.3±6.9Ma. Because zircon is relatively abundant in some samples of quartz diorite, it is possible that these dates represent the times of crystallisation of the mafic and felsic phases of the complex, respectively. The combined populations give a result of 252.6±5.3Ma, close to the Permian-Triassic boundary. A late Permian to Early Triassic age is assigned to the Mount Seaview Igneous Complex.

Most of the recorded production from the Barmundoo Goldfield comes from the area around Mount Seaview, particularly Griffiths Hill. The gold deposits are mainly confined to the felsic phase of the intrusion, and include quartz veins along the walls of andesitic dykes and stockwork of thin quartz veins associated with the granite phase, concentrated within a brecciated zone.

ZigZag Tonalite

The Zig Zag Tonalite is an ovoid intrusive ~2km by 1.5km located just north of Galloway Plains Igneous Complex. Poorly outcropping, handspecimens show a pale grey medium-grained hornblende-biotite tonalite. Plagioclase forms ~45% of rock. Quartz (35% of the rock) and K-feldspar (<5%) form interstitial grains. Mafic minerals comprise 15%, with biotite more abundant than green hornblende. Accessories include opaques, sphene, apatite, and zircon, and some secondary epidote is also present.

The pluton intrudes the Mount Alma Formation and the Rockhampton Group, and does not appear to be offset by the faulted contact between these two units.

No dating has been carried out. The Zig Zag Tonalite is assigned a Permian to Triassic age.

No mineralisation is known to be associated with the Zig Zag Tonalite. However, analysis of fresh material from the outcrop in the type area returned a high copper content of 2120ppm.

Mannersley Quartz Microdiorite

The Mannersley Quartz Microdiorite is a small body 2.5km by 1km located north of the Galloway Plains Igneous Complex and just east of the Zig Zag Tonalite. The intrusive records low radiometric and a patchy moderate magnetic response. Detailed company mapping found that the intrusion is dominantly quartz diorite porphyry surrounding a smaller stock of medium to coarse-grained biotite quartz diorite (Taube, 1976). A sample from the type area is a pink to grey porphyritic quartz microdiorite.

The Mannersley Quartz Microdiorite intrudes the Rockhampton Group. No dating has been carried out, and a Permian to Triassic age is assigned.

The Mannersley Porphyry Copper prospect is hosted in this body. According to Taube (1976), the mineralisation is mainly confined to the late stage coarser-grained quartz diorite. Located between the Zig Zag Tonalite and the Mannersley Quartz Microdiorite is the Mount Grim magnetite-copper-gold skarn.

Castle Tower Granite

The Castle Tower Granite forms the highly rugged country of the Many Peaks Range, much of which remains heavily forested. The batholith is north-south trending, 45km long and up to 10km wide. The dominant rock type is a pink to buff, medium-grained, equigranular, leucocratic, biotite syenogranite. Quartz and microperthitic K-feldspar are present in approximately equal proportions (each ~40% of the rock). Plagioclase comprises up to 15% of the rock, and contains myrmekitic intergrowths at contacts with K-feldspar grains. Dark brown biotite flakes make up 5% of the rock. Accessories include opaques, zircon, and tourmaline. Prominent joint sets are evident, oriented north-north-west and north-north-east in the north and east–west in the south. The pluton has a very high radiometric and weakly magnetic response. Geochemically similar, the Castletower Granite and the Miriam Vale Granodiorite (a composite batholith) form the Miriam Vale group. This group has high TiO_2, total alkalis, Ce, Y and Zr, high K_2O and Rb at high SiO_2 contents, and low Sr like the Ridgelands group.

The Castletower Granite intrudes the Calliope beds and Wandilla Formation. It is assumed to intrude the Miriam Vale Granodiorite to the east, although contact relationships have not been observed. The nature of its contact with unnamed Triassic volcanics to the south in the Bobby Range is also uncertain, and may be either intrusive or an unconformity. The granite is intruded by the Norton Tonalite and by a sill-like gabbro east of Norton Creek.

No dating has been carried out on the Castletower Granite, and it is assigned a Permian to Triassic age on the basis of its relationships.

The Castletower Granite is largely devoid of mineralisation, but it does host the deposits of the Mount Jacob Goldfield. The source of this mineralisation is considered to be the unnamed tonalitic pluton intruding the Castletower Granite along Oaky Creek.

Norton Tonalite

An irregularly shaped intrusion, located 35km south-south-east of Calliope, is named the Norton Tonalite. This intrusive is interpreted to be off-set by a 2km sinistral strike-slip fault trending north-west. It forms relatively low country surrounded by the more rugged Castle Tower Granite. Petrographically the rock is a grey medium-grained hornblende-biotite tonalite. Plagioclase makes up ~60% of the rock. Anhedral quartz comprises ~30%, with very sparse K-feldspar as interstitial to poikilitic crystals. The proportion of mafic minerals is no more than 10% of the rock, with biotite more abundant than hornblende. Accessory minerals include opaque grains, apatite, sphene, zircon, and secondary epidote.

The Norton Tonalite has a low to moderate magnetic response and is dark red in colour in radiometric images. Geochemically it is characterised by high Al_2O_3, CaO, and Sr, and low TiO_2, MgO, and total alkalis. K_2O, Ce, Rb, Th, Y and Zr are all low and the tonalite is therefore included in the Dumgree group.

It intrudes the Castle Tower Granite, the Mirium Vale Granodiorite and the Wandilla Formation. A Permo-Triassic age has been assigned to this intrusive.

The Norton Tonalite hosts numerous sulphide-rich gold-bearing reefs worked as the Norton Goldfield. A similar granodioritic to tonalitic intrusive cuts the Castle Tower Granite ~15km to the south-south-east of the Norton Tonalite and appears to be associated with mineralisation of the Eastern Boyne Goldfield.

Pack Granite

Two small intrusions <1km in diameter have been mapped as the Pack Granite. These intrusions are located 35km south-south-west of Calliope. A strongly jointed pink medium-grained leucocratic muscovite-biotite granite to granodiorite, these bodies intrude rocks of the Rockhampton Group and Mount Alma Formation. Petrographic descriptions show quartz and plagioclase are present in approximately equal amounts, constituting ~80% of the rock. K-feldspar (15% of rock) is mainly interstitial, but also rims plagioclase. Biotite, muscovite and opaques together make up only ~5% of the rock. Accessories include apatite and zircon.

A Permo-Triassic age has been assigned to the Pack Granite.

Gold has been mined from a sulphide-bearing quartz vein in the western outcrop of this granite, and this appears to have been the source for alluvial gold workings in Crow Creek.

Diglum Granodiorite

A zoned, north-east south-west elongate intrusive ~13km long and 5km wide, the Diglum Granodiorite has a core of pinkish grey medium-grained biotite-hornblende granodiorite which is surrounded by grey medium-grained augite-hornblende-biotite tonalite and biotite-hornblende quartz diorite. Petrographic descriptions of the central, more felsic phase show plagioclase comprising about half of the rock. In some specimens, quartz (20–30% of rock) and K-feldspar (15–25%) form a granophyric groundmass interstitial to the plagioclase laths. In others, quartz occurs as equant anhedral grains, and K-feldspar as interstitial grains that locally rim and are optically continuous with plagioclase. Mafic minerals comprise ~10% of the rock, and either biotite or hornblende can be dominant. Accessory minerals include opaques, apatite, sphene and zircon. The outer phase has plagioclase making up from 55–70% of the rock. Quartz ranges from 10–20% as interstitial to poikilitic grains. K-feldspar is never more than 5%, and forms small interstitial grains. Mafic minerals comprise from 15–20% of the rock. Overall, biotite is most abundant, and in most samples is accompanied by green hornblende with relict augite cores. Quartz diorite from the western end of the pluton contains more hornblende than biotite. Accessory minerals include opaques, apatite, sphene, and zircon.

Company exploration drilling indicates that the strongly magnetic phase at the north-eastern extremity of the pluton is a dark grey hornblende or hornblende-augite gabbro with 5–10% magnetite (Neale, 1975). Drilling by Newcrest Mining Ltd (Rigby, 1991) confirmed the presence of magnetite-rich gabbro, and also revealed the existence of a thin zone of granodioritic rocks to the east. The spatial relationships of these phases suggest that the granodiorite phase intruded the tonalite-quartz diorite phase, and that the strongly magnetic gabbro in the north-east was a separate and possibly unrelated intrusion.

The Diglum Granodiorite intrudes the Mount Mount Alma Formation and Rockhampton Group. Roof pendants attributed to the Rockhampton Group are scattered across the north-eastern part of the intrusion. The pluton is cut by a north-south trending andesitic dyke that forms a prominent ridge 4km long. Airborne magnetic data suggest that it is also intruded by some members of a north-west trending dyke swarm extending from the Littlemore Granodiorite to the Diglum Granodiorite. Two samples from the tonalitic phase have been dated. Webb & McDougall (1968) obtained K-Ar ages of 217±4Ma from hornblende and 221±4Ma from biotite, and Muggeridge (1973) obtained an Ar-Ar date of 222±8Ma from biotite. These dates indicate a Late Triassic age.

The geochemistry of the Diglum Granodiorite places it within the Monal group, which comprises the Monal Granodiorite, Diglum Granodiorite, Bocoolima Granodiorite, and Munholme Quartz Diorite.

Skarn mineralisation is recorded in roof pendants in the north-east of the intrusive. The skarns contain garnet and magnetite, with minor amounts of copper mineralisation and local development of wollastonite. Within the intrusion itself, geochemical surveys led to the discovery of a small area of anomalous copper and molybdenum values associated with leached cap rocks, called the Booreco Creek prospect (Carpentaria Exploration Company Pty Ltd, 1974).

Riverston Granodiorite

The Riverston Granodiorite is a small rectangular shaped body 3km by 2km located 8km east-south-east of Calliope, at the northern edge of Lake Awoonga. The intrusive is clearly outlined on images derived from airborne radiometric and magnetic data. Its radiometric response is dominated by potassium, giving it a deep red colour, and it has a moderate to high magnetic signature. The intrusive was not examined during the Yarrol mapping program, but company exploration reports discuss the main rock type as a grey, equigranular to porphyritic biotite granodiorite to diorite. Petrographic descriptions do not indicate the presence of K-feldspar, noting that some samples are trondhjemite (Amax Australian Ventures Ltd, 1976), but the radiometric signature suggests that the pluton as a whole contains a significant amount of potassium. Within the area covered by the granodiorite are numerous elongate east-west trending bodies of rhyolite and microgranite. Their shape suggests that they are dykes, but they are more altered and fractured than the granodiorite, and contact relations are ambiguous. If older than the granodiorite, they appear to be relicts of dykes, because they extend beyond the eastern contact of the pluton (Amax Australian Ventures Ltd, 1976).

No geochemical analyses were available for the Riverston Granodiorite.

The Riverston Granodiorite intrudes the Wandilla Formation. The age is unknown but assigned as Permo-Triassic.

Old gold workings associated with the intrusion are centred on an area of intense brecciation, silicification and argillic alteration that forms a small hill and is interpreted as a breccia pipe 300m by 150m. There is also an area of quartz stockworking in porphyritic rhyolite that is anomalous in copper and molybdenum. Horton (1982) classified the Riverston prospect as a porphyry style deposit.

Munholme Quartz Diorite

The Munholme Quartz Diorite is a small intrusive body 2.5km by 1.5km in extent, located on the western side of Munholme Creek ~40km north of Monto. The dominant rock type is a grey, medium-grained biotite-hornblende quartz diorite to tonalite, with subsidiary biotite-augite-hornblende diorite. Plagioclase is the most abundant mineral in all rock types, making up 70% or more. Mafic minerals comprise 20–30% of the rocks. Pale green hornblende is dominant, often with augite cores. The amount of relict augite decreases as the proportion of quartz increases. Biotite is always present but is subordinate to hornblende. Very pale secondary amphibole in some specimens replaces hypersthene, and epidote occurs locally. Minor and accessory minerals include opaque grains, apatite, sphene and zircon. The intrusion has a moderate to low radiometric signature that gives a red colour on images derived from airborne data. Despite moderately strong susceptibility readings averaging 2175 x 10^{-5} SI units, it has a relatively low overall magnetic response, and is surrounded by a prominent magnetic halo developed in the contact rocks.

Geochemically, the Munholme Quartz Diorite forms part of the Monal group. It intrudes the Three Moon Conglomerate and Rockhampton Group, which forms some roof pendants. The intrusion has not been dated. It is assigned a Permian to Triassic age consistent with most plutons in the region. The intrusion hosts a variety of mineralisation styles. The Silver Star deposit consists of silver and base metal mineralisation hosted by barite-quartz-carbonate veins in altered diorite. To the east of the Silver Star, disseminated and fracture coatings of pyrite, chalcopyrite and molybdenite occurs in altered quartz diorite and replacing the matrix in breccias and conglomerates of the Rockhampton Group. Horton (1982) described this mineralisation as a porphyry-style deposit but it is discussed here as an intrusive-related vein style deposit. In the northern part of the intrusion, gold is associated with sulphides in calcite-quartz and calcite-chlorite-quartz veins in altered diorite to tonalite and in contact rocks of the Rockhampton Group.

Ridgelands Granodiorite

The Ridgelands Granodiorite is centred 20km north-west of Rockhampton and comprises a central boomerang-shaped body and four smaller areas of outcrop. The main body extends from Ridgelands township in the east, almost to Mount Salmon in the west, and to the Fitzroy River in the north. Smaller bodies assigned to the Ridgelands Granodiorite crop out around Sugarloaf Mountain, Lake Learmouth and Third Sugarloaf, Eden Bann Weir and south-west of Wattlebank homestead. There is considerable variation in the composition of this unit. In the Eden Bann area medium-grained equigranular foliated tonalite is evident. This rock has euhedral, twinned hornblende (20% of the rock) dominant to biotite (5%). Sparse metasedimentary xenoliths and abundant igneous xenoliths (microdiorite and equigranular granodiorite) are evident. In the Wattlebank area there are exposures of microgranodiorite with fine biotite as the principal mafic mineral and a medium-grained, equigranular biotite-hornblende granodiorite. Several variants of this unit including a pink, medium to coarse-grained, biotite-bearing pegmatite; a very light grey to white, sphene-bearing, hornblende pyroxene tonalite; and a slightly foliated, hornblende biotite microgranodiorite crop out around Gullyview homestead. The central mass of the intrusive, around Moonlight and Big House homesteads, is primarily an equigranular granodiorite and tonalite that has been intruded by biotite-bearing microgranite, diorite and gabbro. Biotite and hornblende are generally present in subequal amounts, and comprise a total of 10–20% of the rock. Mafic xenoliths, including pyrite-bearing andesite, and microdiorite, up to 40cm in diameter are common. Between Station and Two Mile Creeks, a small intrusive body, and numerous north-west-trending narrow dykes of biotite microgranite intrude granodiorite. Three small mappable gabbro-diorite bodies crop out around the Ridgelands township. The rocks are generally dark grey, equigranular to sparsely porphyritic, and locally pegmatitic. In the Mount Sugarloaf area rock types include biotite-hornblende-quartz diorite, diorite, biotite-hornblende tonalite and granodiorite. Hornblende is the dominant mafic mineral.

The geochemistry of the Ridgelands Granodiorite defines the Ridgelands group, which comprises the Ridgelands Granodiorite, Wattlebank Granodiorite, and Lookerbie Igneous Complex.

The Ridgelands Granodiorite intrudes the Craigilee beds, Mount Alma Formation, Rockhampton Group, and undifferentiated early Permian rocks. It is overlain by Cretaceous basalt and trachyte and intruded by Cretaceous trachyte to rhyolite plugs and dykes. The previously reported Permian date for the Ridgelands Granodiorite was based on a K-Ar hornblende radiometric date of 266Ma obtained from a sample from near Eden Bann homestead. Recent age dating of a sample collected from the main intrusive body using

Rb/Sr techniques returned a date of 251±2Ma. The unit is regarded as Permo-Triassic.

Approximately 168kg of gold was mined from the Ridgelands workings ~1km south of the Ridgelands township. This mineralisation is probably skarn related and formed at the contact of a small gabbroic phase and sediments of the Mount Mount Alma Formation and Rockhampton Group.

Targinie Quartz Monzonite

The Targinie Quartz Monzonite is an elongate intrusion extending for ~11km north from Mount Sugarloaf. It forms the eastern foothills of the Mount Larcom Range. Within the pluton, rock types range from granite to granodiorite, with quartz monzonite being dominant. The peak of Mount Larcom is an alteration zone consisting of equal proportions of alunite and quartz that is related to the intrusion. This unit returns a high radiometric response.

Geochemical analysis of the Targinie Quartz Monzonite returned anomalously high results, including total alkalis. The intrusive did not fit within the groups defined by Murray (in preparation).

Polymetallic veins are identified in the Targinie Granite and in adjacent Doonside Formation and a small iron skarn deposit is located adjacent to the Targinie Quartz Monzonite in the Balnagowan Volcanic Member.

Miriam Vale Granodiorite

The Miriam Vale Granodiorite is a large composite batholith that is mainly exposed on Miriam Vale and Rosedale sheets. Outcrops in the Yarrol assessment area are restricted to the south-eastern corner of the Gladstone sheet, where it intrudes the Shoalwater Formation. The main rock types are medium-grained, cream granodiorite and monzogranite, generally with low mafic contents. The rocks are mostly highly weathered and are poorly exposed.

The Miriam Vale Granodiorite (a composite batholith) along with the Castletower Granite forms a geochemically distinct group. This group has high TiO_2, total alkalis, Ce, Y and Zr, high K_2O and Rb at high SiO_2 contents, and low Sr like the Ridgelands group.

Bajool Quartz Diorite

The Bajool Quartz Diorite extends west and south from the township of Bajool. Outcrop is sparse, and most of the intrusion is covered by a thick regolith layer of decomposed granitoid, which forms a plain. The full extent of the intrusion is evident on images of airborne magnetic data, which also show conspicuous concentric zoning. Outcrops are dominantly an equigranular quartz diorite.

The Bajool Quartz Diorite intrudes the Capella Creek Group, Erebus beds, unnamed Middle Devonian gabbros, Mount Alma Formation, and Rockhampton Group. A Late Permian to Early Triassic age is suggested by a K-Ar date of 249±5Ma on sericite from a mineralised breccia pipe at Limonite Hill ~5km south of Bajool (Ford & others, 1976).

Cecilwood Quartz Diorite

The Cecilwood Quartz Diorite is located south of the Bajool Quartz Diorite where it crops out poorly and ranges in composition from diorite to quartz diorite. It intrudes the Capella Creek Group and the Mount Alma Formation.

Unnamed intrusives

Several unnamed intrusions and dykes, ranging in composition from gabbro through diorite to granodiorite, occur in the Yarrol Province. These are assumed to be Permo-Triassic in age.

An elongate unnamed gabbro (PRg) 3km long and 1km wide, with a north-west orientation is located 4km north-west of the Archer railway siding, 15km north-west of Bajool. No outcrop is present, however, a magnetic high is evident and company drilling has intersected gabbro with carbonate veins and minor amounts of disseminated pyrite. The gabbro intrudes the Rockhampton Group.

Glassford Igneous Complex

Field mapping by the GSQ (Yarrol Project Team, 1997) subdivided the Glassford Igneous Complex into 13 separate units: Radley Nepheline Syenite, Burns Spur Nepheline Monzosyenite, Judas Trachybasalt, Ridler Monzonite, Tolbar Breccia, Deception Quartz Monzonite, Littlemore Granodiorite, Lawyer Granite, Monal Granodiorite, Robert Granite, Rule Gabbro, and unnamed granite and rhyolite. Two of these units are themselves composite.

The western end of the Glassford Igneous Complex displays a 'doughnut' type magnetic pattern caused by a strongly magnetic hornfelsed rim almost completely surrounding an quartz diorite to granite intrusion, the Monal Granodiorite. The **Monal Granodiorite** is divided into two phases, one ranging from quartz diorite to granodiorite and the other phase ranging from granodiorite to granite. The felsic phase appears to intrude the marginal granodiorite-tonalite phase. Swarms of east-north-east trending dykes, dominantly of rhyolite but locally of more intermediate composition, cut the western part of the granodiorite between Monal and Spring Creek.

Geochemically, the Monal Granodiorite falls within the Monal group and is intermediate in composition between the Dumgree and Littlemore groups.

The Monal Granodiorite intrudes and has hornfelsed the Devonian–Carboniferous Three Moon Conglomerate. It is intruded by the Cretaceous Burns Spur Nepheline Monzonite and the Ridler Monzonite, by a rhyolitic dyke swarm related to the Triassic Dooloo Tops Volcanics, and by Tertiary basalt plugs. The Dooloo Tops Volcanics are interpreted to overlie the Monal Granodiorite, and the northern end of the plateau forming Dooloo Tops appears to be an exhumed Triassic weathering profile developed on the granodiorite. The relative age relationship between the Monal Granodiorite and the Littlemore Granodiorite is unknown, however, the Monal Granodiorite is considered to be Triassic because of its close relationship with the Littlemore Granodiorite.

Numerous gold workings of the Monal Goldfield are located around the periphery of the Monal Granodiorite, implying that mineralisation was related to the intrusion.

The **Littlemore Granodiorite** forms the north-eastern and largest part of the Glassford Igneous Complex. It extends in a west-south-west trending belt ~20km long and 6km wide along Ridler Creek from the township of Ubobo to Mount Sugarloaf. The magnetic pattern suggests the presence of at least two discrete plutons (CR29288), but these have not been distinguished either in the field or by petrography and geochemistry. Modelling of north–south and east–west profiles across the northern part of the Littlemore Granodiorite shows a weakly magnetic central intrusive with a moderately magnetic northern rim (CR29288). The rocks are grey medium to coarse-grained equigranular biotite-hornblende granodiorite and quartz monzodiorite. Locally, the rocks show significant alteration. One altered sample in the type area along Connell Creek contains rare flakes of molybdenite up to 10mm across, and sparse small grains of tourmaline.

Geochemically, the Littlemore Granodiorite, together with the Lawyer Granite, define the Littlemore group. This group is high in total alkalis, K_2O, Rb, and Th. Ce and Sr are high and show a decreasing trend with increasing SiO_2. Y and particularly Zr exhibit curved trends on Harker diagrams, indicating fractionation.

Webb & McDougall (1968) obtained K-Ar dates of 221±4Ma (biotite) and 216±4Ma (hornblende) from a sample of Littlemore Granodiorite, indicating a Late Triassic age. Interpretation of magnetic data has the Rule Gabbro and Robert Granite intruding it successively, and the Ridler Monzonite also intruding it. However, a U-Pb zircon age of 230.2±3.7Ma from the Robert Granite suggests either that the interpreted intrusive relationship is incorrect, or that the K-Ar dates are too young due to Ar loss. The Littlemore Granodiorite has been assigned a Triassic age. Its relationship with the Monal Granodiorite is not known. The eastern edge of the intrusion is cut off by the fault, which forms the western margin of the Tertiary Nagoorin Graben.

The Littlemore scheelite deposit is associated with a porphyry dyke that occurs in altered rocks of the Littlemore Granodiorite. Disseminated copper mineralisation has recently been discovered in outcrops on the northern flanks of Mount Robert (McGraths and Plumtree prospects). Copper also occurs in skarns formed in contact rocks of the Rockhampton Group both to the north (Mount Hector-Monument area) and south (Hourigans prospect) of the intrusion. Calc-silicates have replaced limestone lenses in unnamed Permian sedimentary rocks to the east of the Littlemore Granodiorite, but no sulphides have been observed.

The **Lawyer Granite** covers an area of ~30km^2 between Coppermine Creek in the north and Glassford Creek in the south. This southern part of the Glassford Igneous Complex is a zoned pluton ranging from granite in the core to quartz monzodiorite at the margin. The granite core makes up most of this area, and forms a roughly rectangular mass 5km from north to south and 4km from east to west. The marginal quartz monzodiorite is thin and locally discontinuous around the eastern, southern and western sides of the granite, and more extensive along the northern edge. Its magnetic pattern suggests that it represents a single equant pluton, but it may originally have extended further to the north, as it appears to be cut off in this direction by the strongly magnetic Rule Gabbro. Foliated quartz gabbro occurs where Coppermine Creek crosses the eastern edge of the intrusion.

The Lawyer Granite and Littlemore Granodiorite are geochemically the type intrusions for the Littlemore group.

Two samples of the Lawyer Granite have been dated by Webb & McDougall (1968) to give K-Ar dates of 226±4.5Ma (on biotite) and 224±4.5Ma (on hornblende) and for the second sample 226±4.5Ma (on biotite). The results suggest that the two phases are coeval, and of Late Triassic age. However, magnetic data suggests that the Lawyer Granite has been intruded by the Rule Gabbro and the Robert Granite, and therefore by the Deception Granite also. A U-Pb zircon age of 230.2±3.7Ma from the Robert Granite suggests either that the interpreted intrusive relationship is incorrect, or that the K-Ar dates are too young due to Ar loss. The Lawyer Granite has been assigned a Late Triassic age.

The Lawyer Granite intrudes the Carboniferous Rockhampton Group. Tertiary basalt plugs intrude the unit along its south-eastern margin. The relationship of the Lawyer Granite to unnamed Triassic volcanic rocks to the east is unknown.

Mineralisation is associated with the Lawyer Granite with garnet and magnetite-bearing skarns along the western edge of the Lawyer Granite and copper produced from the Blue Bag and Lady Inez skarn deposits of the Glassford Creek mine group. Further south, zinc-rich skarns occur at Mount Sperber. Skarns are also developed along the intrusive contact near Mount Weary. The small dioritic intrusion associated with the Boggy Creek gold prospect is located just east of the Lawyer Granite and may be related to it.

The **Rule Gabbro** forms a prominent elliptical shaped magnetic high on images of the Glassford Igneous Complex produced from airborne magnetic data, between the Littlemore Granodiorite and the Lawyer Granite. The southern part of this anomaly coincides with gabbroic rocks of the Rule Gabbro. Although outcrops cover only a relatively small part of the intense doughnut shaped positive magnetic feature, the Rule Gabbro is considered to be responsible for the anomaly. The Rule Gabbro is an altered, grey, medium to coarse-grained biotite-hornblende-olivine-augite gabbro. Finer grained rocks of the Rule Gabbro are augite microgabbro.

Interpretation of airborne magnetic data suggests that the Rule Gabbro intrudes the Littlemore Granodiorite and Lawyer Granite, and is intruded by the Robert Granite all of which have been given Triassic dates, indicating a Triassic age for the Rule Gabbro. It also intrudes unnamed Permian sedimentary and volcanic rocks along its eastern margin, and is intruded by the Deception Granite. Its relationship with Triassic volcanic rocks, which are interpreted to extend along the eastern side of the Deception Granite as far as the Rule Gabbro, is unknown.

No mineralisation is known to be associated with the Rule Gabbro.

The **Robert Granite** is a relatively non-magnetic leucocratic granite to quartz monzonite with granophyric texture which occurs in the centre of the doughnut shaped magnetic high attributed to the Rule Gabbro. Geochemical analyses of the quartz monzonite showed it is more alkaline than other Permian-Triassic intrusions.

The Robert Granite intrudes unnamed Permian rocks to the east, the Littlemore Granodiorite to the north, and the Rule Gabbro and Lawyer Granite to the south. A U-Pb zircon age of 230.2±3.7Ma from the Robert Granite indicates a probably Late Triassic age.

The Robert Granite is not known to be associated with any mineralisation.

The **Deception Quartz Monzonite** covers a roughly triangular area 2.5km from east to west and just over 2km from north to south along Deception Creek, 8km west-south-west of the township of Many Peaks. It is a pink, medium-grained, equigranular, leucocratic hornblende-biotite quartz monzonite to granite. Micrographic textures and the presence of miarolitic cavities, some now filled with secondary minerals, indicate intrusion at shallow levels. Large andesitic dykes are common in the unit and comprise up to 50% of some outcrops.

The monzonite is a relatively small mass very similar to the quartz-poor parts of the Robert Granite, and the two intrusions may be related. No geochemical data is available. Correlation with the Robert Granite suggests a Triassic age for this intrusive. The Deception Quartz Monzonite intrudes Permian sedimentary and volcanic rocks and the Rule Gabbro. No mineralisation is known to be associated with this unit.

Wingfield Granite

The Wingfield Granite forms a major component of the Rawbelle Batholith, cropping out in part on the Scoria sheet. It covers a very large area and includes several variants, although the most common rock type is a grey and pink, medium-grained porphyritic hornblende-biotite granite, characterised by large pink K-feldspar megacrysts up to 4cm. Variants include: pale grey, medium-grained, even grained hornblende-biotite granodiorite; biotite-hornblende granodiorite; and a slightly porphyritic hornblende-biotite granodiorite. The aeromagnetic response over the pluton shows several areas of lower magnetic intensity can be delineated and are probably associated with alteration.

Although outcrop is poor, the Wingfield Granite is inferred to intrude both the Yaparaba and Camboon Volcanics. The relationship between the Wingfield Granite and the Harrami Igneous Complex is uncertain, although the regular outline of the contact suggests that the Wingfield Granite is younger. Magnetic images show a distinct highly magnetic rim around the pluton, particularly in the east under the cover of Mulgildie Basin sedimentary rocks. This is inferred to be due to hornfelsing of the Yarrol Basin succession. Magnetic highs to the north and west may be partly hornfels-related, but are due mainly to highly magnetic plutons such as the Harrami Complex and Kariboe Gabbro.

K-Ar dating on six samples by Webb & McDougall (1968) gave Early to middle Triassic ages ranging from 233–247Ma. These may be partly reset, so the age is regarded to be Late Permian to Early Triassic.

Jurassic to Cretaceous Intrusives

Glassford Igneous Complex

The **Ridler Monzonite** is an elongate north-east trending intrusion 7km long and 2.5km wide which extends along the north side of Ridler Creek from Mount Sugarloaf to the Dawes Range. The Ridler Monzonite covers the full compositional range from syenite, through monzonite and quartz monzodiorite, to monzogabbro and gabbro. The average composition is close to monzonite. Generally, the rocks can be distinguished from Triassic granitoids of the Glassford Igneous Complex by their low content of quartz and mafic minerals, finer grain size, lack of alteration, and close jointing. Syenite is found mainly on Mount Sugarloaf. Monzonite occurs on the lower ridges west and north of Mount Sugarloaf. The rock is pale grey in colour, leucocratic (mafic minerals ~10%), foliated, and in hand specimen is similar to the syenite forming Mount Sugarloaf. Quartz monzodiorite is the main rock type along Tollbar Creek upstream from the Tollbar Breccia. It is a relatively uniform grey, medium-grained equigranular hornblende quartz monzodiorite with or without biotite. Monzogabbro and gabbro are found at two separate localities along Tollbar Creek, both occur within magnetic highs, suggesting that gabbro might be more abundant at depth. Monzogabbro occurs as dykes cutting gabbro in Tollbar Creek north of Mount Sugarloaf. The rock is finer grained than the gabbro, and pinkish in colour.

The Ridler Monzonite intrudes the Carboniferous Rockhampton Group, the Triassic Monal Granodiorite and Littlemore Granodiorite. Contact metamorphic rocks in the Rockhampton Group along the north-west side of the intrusion are locally rich in fluorite. The monzonite is intruded by all the other Cretaceous units of the Glassford Igneous Complex: the Radley Nepheline Syenite, Burns Spur Nepheline Monzosyenite, Judas Trachybasalt, Tollbar Breccia, and unnamed granite and rhyolite. Neale (1968) recorded dykes of the Radley Nepheline Syenite intruding the Ridler Monzonite on Mount Sugarloaf.

Anomalous copper levels in rocks and drainage samples in the area of the Ridler Monzonite have been of interest to several exploration companies, but no prospects have been identified. Rare boulders of fluorite have been recorded by the GSQ during the 1994 field season in a tributary of Tolbar Creek at the northern contact of the Ridler Monzonite with the Rockhampton Group 3.5km west of Mount Sugarloaf.

The **Radley Nepheline Syenite** forms a triangular-shaped mass ~1.5km^2 in an area between Camp Creek in the north and Tollbar Creek in the south. The Radley Nepheline Syenite is a multi-phase intrusion, with up to three generations of dykes, both coarser and finer grained than the host rock (Neale, 1968). The rocks consist mainly of K-feldspar, with or without subordinate plagioclase, and varying proportions of nepheline and a sodalite group mineral. Mafic minerals include aegirine, ferrohastingsite, melanite garnet and lepidomelane.

There are two types of breccia along the western edge of the syenite intrusion, both of which are non-magnetic. The smaller outcrop gives a similar radiometric signature to the Radley Syenite, and is mapped as a phase of that intrusion. This breccia contains plutonic rock fragments, and large greenish-black pyroxene and biotite crystals. Dykes or large clasts in this area contain prominent phenocrysts of potash feldspar.

A second small feldspathoid-bearing intrusion, the Burns Spur Nepheline Monzosyenite, occurs ~6km south-west of the Radley Nepheline Syenite, and covers the area of the headwaters of Ridler Creek and its tributaries. The Burns Spur Nepheline Monzosyenite is a pink to fawn medium to coarse-grained equigranular leucocratic nepheline monzosyenite with local concentrations of large finer grained grey inclusions. Sulphides, mainly pyrite, are relatively abundant along irregular joint planes.

The **Burns Spur Nepheline Monzosyenite** intrudes the Triassic Monal Granodiorite and the Cretaceous Ridler Monzonite. By correlation with the Radley Nepheline Syenite, the unit is assigned a Cretaceous age.

At the old Burns Spur Copper Mine mineralisation appears to be associated with syenite dykes.

The **Judas Trachybasalt** forms as a roughly circular body apparently intruding the Ridler Monzonite. The trachybasalt is grey in colour with porphyritic biotite-hornblended-augite. The trachybasalt is locally cut by porphyritic dykes.

The **Tollbar Breccia** occupies an area west of Mount Sugarloaf >2km long and averaging ~¾km wide, trending west-north-west between Ridler Creek to the east and Tollbar Creek near the western end. The breccia is coarse with angular to rounded clasts mainly, but not exclusively, of altered granitic rocks in a limonitic matrix.

A number of costeans along the banks of Tollbar Creek show that this rock type has been the target of past exploration.

A small mass of **unnamed granite** ~2.5km south of Mount Sugarloaf differs from all other Cretaceous intrusions within the Glassford Igneous Complex, by having a high quartz content. The rock consists essentially of K-feldspar (~60%) and quartz (35%). Minor biotite is present as small, slightly pleochroic crystals. The granite is almost entirely surrounded by, and therefore assumed to intrude, the Ridler Monzonite. It also intrudes the Monal Granodiorite. A Cretaceous age has been assigned to the intrusion based on these relationships.

No mineralisation is known to be associated with this intrusion.

Goodicum Gabbro

The Goondicum Gabbro is an almost circular intrusion ~7km across, located 30km east of Monto. The intrusion forms low cleared country with a raised hornfels rim. A gabbroic lopolith, the body is layered dipping towards the centre at 20–30°. The total thickness represented in surface exposures is ~1500m. Both compositional layering and igneous lamination are present. Rock types include olivine gabbro, troctolite, leucogabbro, anorthosite, ferrigabbro, layers rich in magnetite and ilmenite, and marginal hornblende gabbro. The main cumulus minerals are plagioclase (labradorite), olivine, and titaniferous augite. Biotite is common, and locally abundant.

Most of the intrusion consists of laminated gabbros that can be divided into 19 evenly spaced alternating leucogabbro and olivine gabbro layers (Groen, 1993). Walsh (1972) noted that magnetite-rich ferrigabbros form two elongate bodies conformable with the layering. In contrast, Groen (1993) considered that these two arcuate bodies dipped more steeply than the layering, and interpreted them as later intrusions into a partially solidified crystal mush. Peralkaline syenite forms outward dipping ring dykes (Groen, 1993). The gabbroic rocks are mildly alkaline, as suggested by the ubiquitous presence of titanaugite and the relative abundance of biotite, and the syenite is peralkaline (Groen, 1993). The restriction of the syenite dykes to the area covered by the Goondicum Gabbro suggests a genetic relationship. Hornblende from gabbro near the southern margin of the intrusion gave an age of 96Ma, or mid-Cretaceous (Groen, 1993). It intrudes the Wandilla Formation and is intruded or overlain by Tertiary basalt.

The intrusion has been explored unsuccessfully for platinum group elements. Currently Monto Minerals NL is producing mineral sand (ilmenite and titano-magnetite) and plagioclase feldspar in a pilot plant from alluvium and colluvial deposits derived from the Goondicum Gabbro. In October 2000, the deposit contained a measured and indicated resource of 79Mt, averaging 5.0% ilmenite and 2.8% titano-magnetite. Resources at Eulogie Park (EPM 9541) are estimated to be very similar to that at Goodicum.

TECTONIC MODEL

The following is a summary of the tectonic history of the Yarrol Province and reflects the most recent interpretations made by the GSQ. The tectono-stratigraphy and metallogeny of the Yarrol Province is shown graphically in the time-space plot (see end of this section).

During the Late Silurian to Middle Devonian the rock units, which were later to form part of the Yarrol Province, were separated from each other and from the main continent of Australia. Each of the four exotic terrane REUs (Calliope, Erebus, Craigilee and Mount Morgan) have distinctive geochemistry suggesting different magmatic histories. Deposition appears to have ceased in the Calliope and Erebus REUs during the last part of the Early Devonian but continued into the late Middle Devonian in the Craigilee and Mount Morgan REUs. Although the actual mechanism is unclear, in terms of whether the different assemblages were amalgamated prior to collision or were incorporated separately into the continental margin, all terranes appear to have reached their present positions, relative to each other at the end of the Middle Devonian.

The simplest model for collision involves formation of the Capella Creek Group above an east-dipping subduction zone and thrusting of the Capella Creek Group over a continental crust that consisted of similar juvenile oceanic terranes. This mechanism is consistent with the interpretation of the Erebus and Calliope beds as older, inactive arc and possibly backarc sequences behind the arc related to the Capella Creek Group (Murray & Blake, submitted). Deformation associated with collision with the Australian continent resulted in folding. Subsequent erosion unroofed some granitoids and locally produced a cleavage.

As a result of the collision the Middle Devonian subduction zone flipped and westerly subduction began. In the early Late Devonian volcanism resumed and an arc developed over the Capella Creek Group and Marble Waterhole beds, extending slightly further west with deposition beginning in a forearc basin to the east of the arc. Geochemistry of the Upper Devonian basalts from the Lochenbar Formation shows they are not as depleted as basaltic rocks from the Capella Creek Group, supporting a reversal of the subduction direction to tap a more enriched mantle source. However, basaltic rocks with backarc characteristics such as those of the Three Moon Conglomerate are not readily explained in this model, although they may be earlier or adjacent backarc sequences caught along the edge of the developing arc. The Upper Devonian rocks are considered to represent a transitional phase in the change from intra-oceanic to a continental margin setting (Murray & Blake, submitted).

The Upper Devonian–Lower Carboniferous sequence is separated from all older stratigraphic assemblages by a regional hiatus. An angular unconformity is evident between the Capella Creek Group and the Mount Hoopbound Formation in the Mount Morgan area (Kirkegaard & others, 1970; Leitch & others, 1992, Hayward & others, 1999). This hiatus is confined to a very short interval spanning the mid- to late Devonian boundary. The Capella Creek Group may have formed a topographic high from the Late Devonian to the earliest Carboniferous, as formations of the same age on either side of it are distinctly different. Upper Devonian formations to the west of the Capella Creek Group (Mount Hoopbound and Balaclava Formations) are usually coarse-grained and have sedimentary structures suggesting shallow marine and subaerial environments, whereas the Upper Devonian Mount Mount Alma Formation to the east, is dominated by fine-grained sediments and possesses sedimentary features which suggest a more distal and deeper marine environment. This distinction is emphasised by structural differences between the western more proximal units, which are gently dipping and lack cleavage, and the distal Mount Alma Formation, which is cleaved over much of its outcrop area. Similarities in geochemistry between basaltic rocks of the Marlborough Metamorphics and the Lochenbar formation indicate that the Marlborough Metamorphics were close to their present position in the Late Devonian (Murray & Blake, submitted).

The arc represented by the Mount Hoopbound Formation and the Lochenbar Formation became inactive by the end of the Late Devonian and shifted to the west to produce a true continental margin arc (the Connors and Auburn Arches). Deposition in the forearc basin continued and covered the Late Devonian arc as well as older basin strata to the east. The central coastal Queensland area developed a major accretionary wedge complex. The cessation of subduction at about the end of the Carboniferous was marked by a transition to an extensional environment, which created a new depositional pattern over the region.

In the early Permian to early Late Permian volcanic units such as the Rookwood Volcanics, and the volcanic rocks of the more marginal Berserker Group were erupted in a backarc setting. The backarc setting is consistent with the extensional event that also formed the Bowen Basin. The Camboon, Mount Benmore, Leura Volcanics are considered to represent the transition from continental margin arc to extension volcanism (Hutton & Withnall, 2002).

The major deformational event affecting rocks of the New England Orogen, the Hunter–Bowen Orogeny, began in the Late Permian. Deformation associated with the Hunter–Bowen Orogeny is episodic and is expressed differently in what are identified as separate structural zones. The Gogango Overfolded Zone is a zone of thin-skinned west-north-west directed thrusting (Fergusson, 1991; Fielding & others, 1994). Typically, there is the development of strong slaty cleavage in mudstone and siltstone, although sandstone and volcanic rocks also commonly have a well-developed foliation. This is generally expressed as an anastomosing fracture cleavage, but in more intense zones, clasts are strongly flattened and commonly stretched. Stretching lineations generally plunge steeply east, and shear-sense indicators are consistent with an east-over-west transport. In the eastern part of the Gogango Overfolded Zone, belts of volcanic rocks and undivided Back Creek Group generally show a consistent eastward younging and have been interpreted as an imbricate stack of thrust sheets. Some fold closures have been seen at outcrop scale, although they are relatively uncommon.

The Yarrol Province is also a fold-thrust belt, but unlike the Gogango Overfolded Zone, thrust sheets must be considerably thicker because of the existence of relatively wide continuous stratigraphic sections in many places. The style of deformation across the Yarrol Province is controlled by the basement rocks and sequences that overlie the Late Silurian to Middle Devonian volcanic arc terranes, these are generally flat lying and only gently folded. The intensity of deformation increases significantly towards the Yarrol fault to the east (Morand, 1993b). There are a number of structural and age relationships that indicate the effect of the Hunter–Bowen Orogen. For example, a significant hiatus is present in the Berserker Subprovince between the Lower Permian Berserker Group and the Upper Permian Warminster Formation. The Middle Permian Dinner Creek Conglomerate was folded in the Hunter–Bowen Orogen but not the overlying Triassic Native Cat Andesite. Massive granitic plutons as old as 270Ma, however, show no evidence of deformation or displacement as indicated by their coincidence with gravity lows (Murray & others, 1989).

In the accretionary wedge the Hunter–Bowen Orogeny is interpreted as small and mesoscopic scale fold events and associated cleavage development. Fergusson & others (1990a, 1993) recorded two main deformations (D_1, D_2) and a less common third deformation (D_3). The earliest D_1 structure is interpreted as having been formed during accretion. It appears as a widespread melange with a steeply dipping scaly to slaty fabric (S_1). The melange developed by layer-parallel extension along fault zones. D_2 and D_3 are interpreted to be Hunter–Bowen events (Fergusson & others, 1990b; 1993). The age of these structures as indicated by metamorphic dates from Facing Island (Fergusson & others, 1993) range from the Permian-Triassic boundary to the Late Triassic. D_2 is described as forming a well-developed subhorizontal to shallow east-dipping cleavage (S_2) with associated folds. D_3 structures form as a conjugate system of steeply dipping strike-slip faults formed by north-east south-west oriented compression, and associated fault breccias in chert. Locally, S_2 is affected by kinks and open folds with a steep north-south axial planar crenulation cleavage.

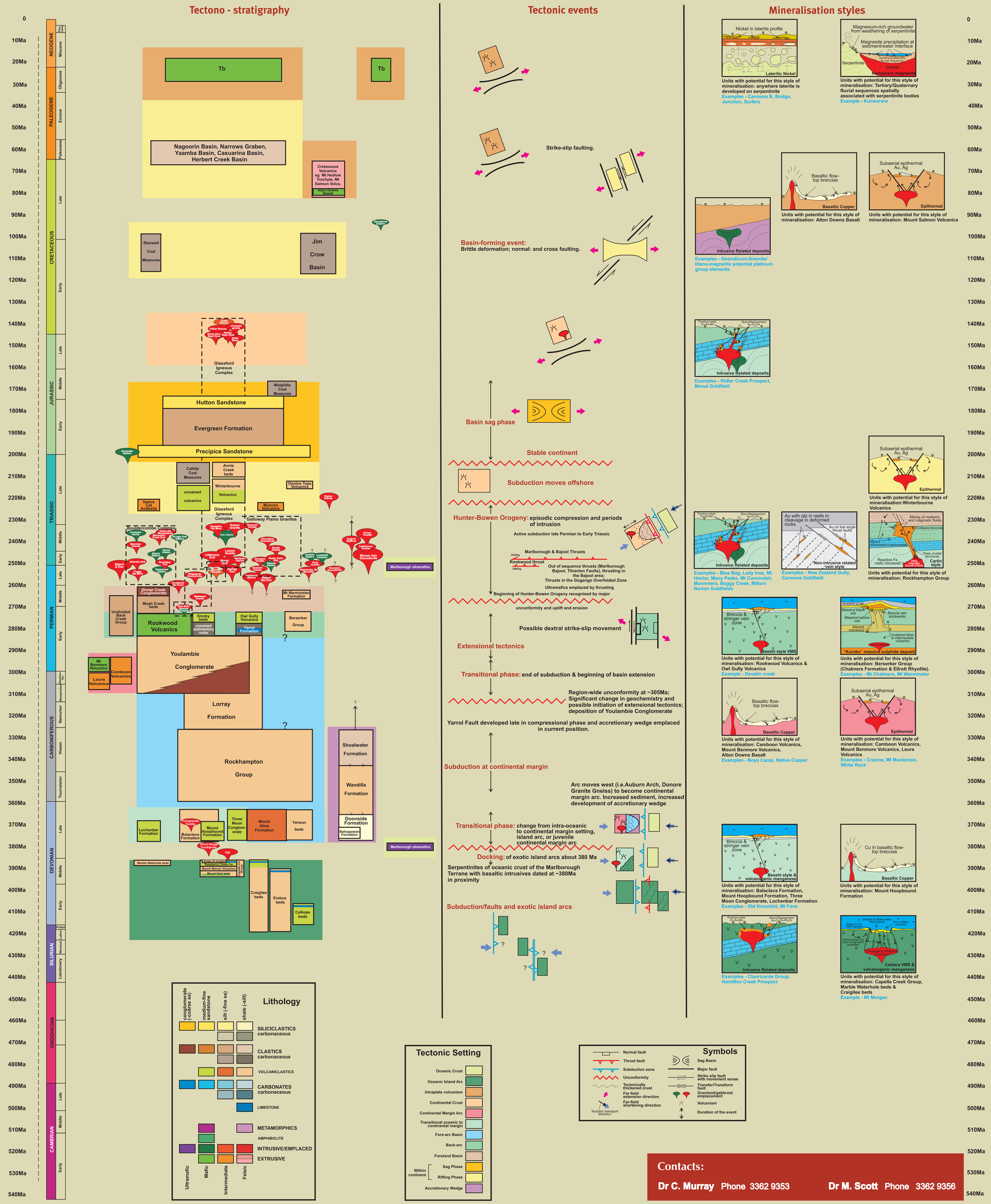
A major period of intrusive activity coincides with the Hunter–Bowen Orogeny (Permian–Triassic). This activity has been proposed by Gust & others (1993) to reflect active subduction, which produced the voluminous Upper Permian and Lower Triassic plutonism in the northern New England Orogen.

The Middle Triassic to Tertiary is regarded as a period dominated by crustal extension. In the Yarrol Province flat-lying bimodal continental volcanics were erupted in the Middle to Late Triassic. Specific basin forming events occurred in the Cretaceous (Stanwell and Jim Crow basins) and Tertiary periods (Nargoorin, Yaamba, Casurina, Biloela, Rossmoya, Aldoga and The Narrows basins). The Cretaceous–Tertiary boundary was also a period of within plate basaltic and rhyoltic volcanism. Volcanic activity also occurred in the Cenozoic with basalt flows, plugs and dykes.

In the Latest Triassic to Middle Jurassic shallow freshwater fluvial and lacustrine, conformable and relatively undeformed sedimentary units reflect a stable, terrestrial environment and are considered to represent thermal relaxation in basin development.

TECTONO-STRATIGRAPHY and METALLOGENY

of the Yarrol Province, central Queensland



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